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ABSTRACT

This teacher's guide is designed to provide science teachers with the necessary guidance and suggestions for teaching organic chemistry. In this book, the diverse field of organic chemistry modules is introduced. The material in this book can be integrated with the other modules in a sequence that helps students to see that chemistry is a unified science. Contents include: Contents include: (1) "Organic Chemistry"; (2) "Hydrocarbons"; (3) "Reactions of Hydrocarbons"; (4) "Alcohols: Oxidized Hydrocarbons"; (5) "Poisons and Chemical Warfare"; (6) "Aldehydes and Ketones"; (7) "Pesticides and Sex Attractants"; (8) "Esters and Acids"; (9) "Organic Bases: The Amines"; (10) "Polymers: The Linking of Molecules"; (11) "Photochemistry: Light and Heat"; and (12) "Drugs: From Aspirin to Hallucinogens". (KHR)

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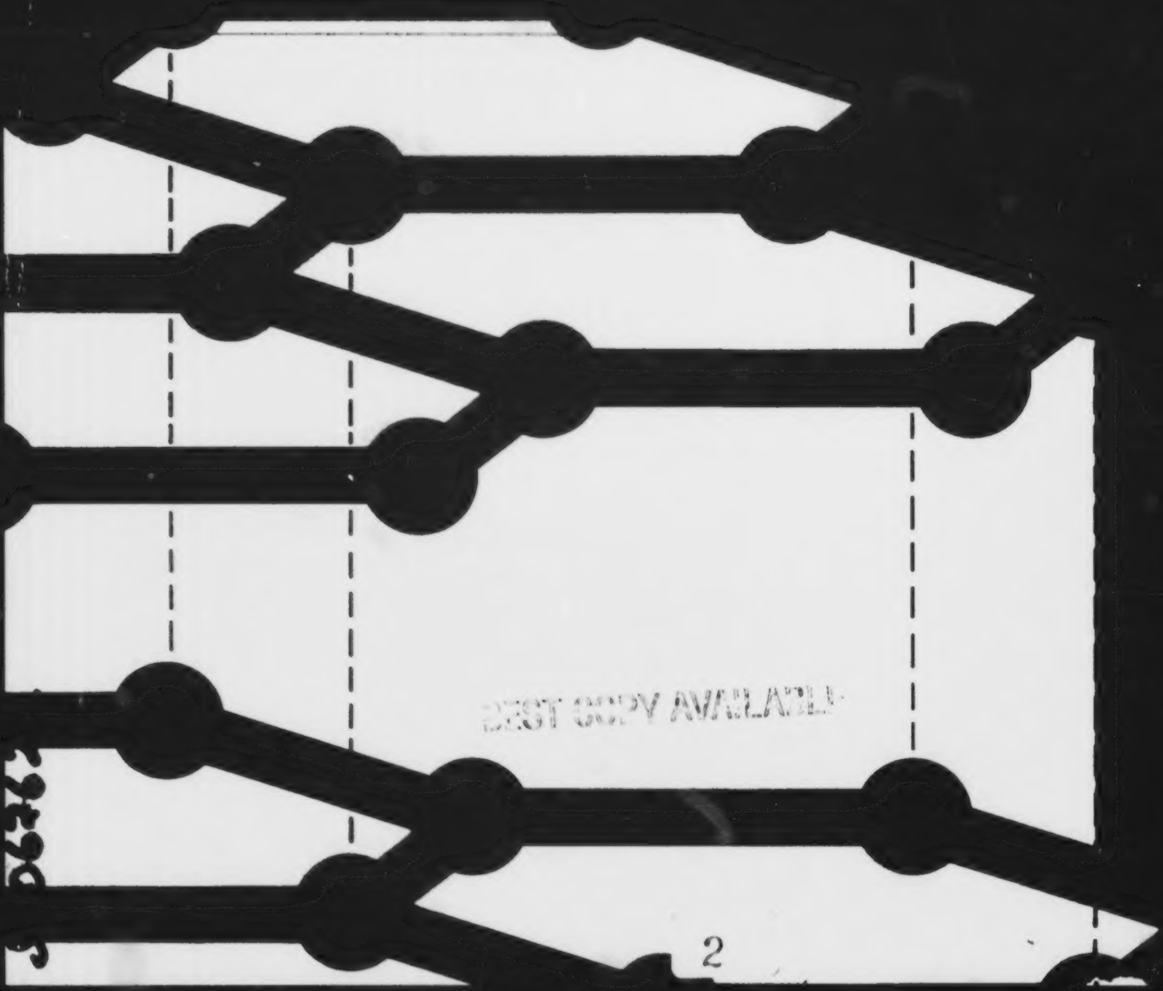
AN ORGANIC CHEMISTRY MODULE



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TEACHER'S GUIDE

FORM AND FUNCTION

AN ORGANIC CHEMISTRY MODULE

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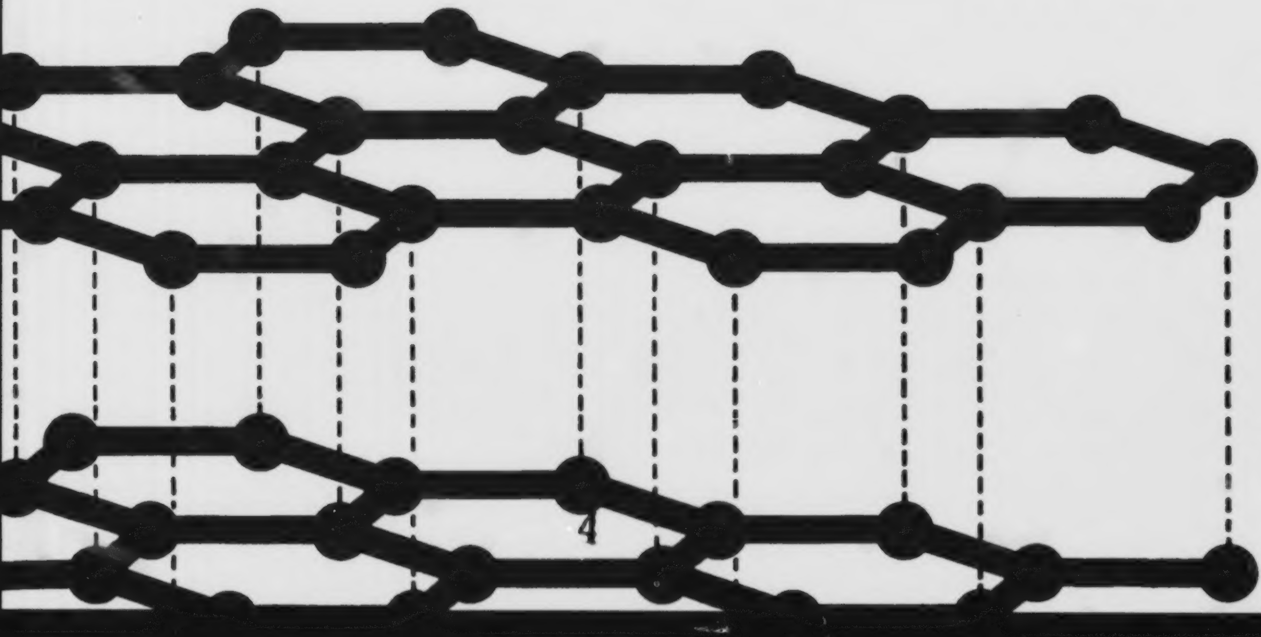

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TEACHER'S GUIDE

FORM AND FUNCTION:
AN ORGANIC CHEMISTRY MODULE

BRUCE JARVIS

Bruce Jarvis arrived at the University of Maryland in 1967, and many people feel that the chemistry department will never be the same again. Sometimes embarrassing to his older colleagues, his graphic explanations during classes and seminars (they have, at times, taken the form of short, costumed one-act plays) are eagerly awaited by his students and coworkers. The exuberance and inquiring mind of Bruce Jarvis have brought a new dimension to chemistry research and teaching activities at the university.

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Paul Mazzocchi came to the University of Maryland in 1967. Since then he has established himself in the chemistry department not only as a good scientist and teacher (winner of the university's Excellence in Teaching Award) but also as a master storyteller. As a young boy growing up on the streets of New York, "Mazzoc" rapidly learned to cope with all of the vagaries of life. More mature now, he continues to bring to the chemistry classroom a certain wisdom, understanding, and humor that go beyond the subject itself.

ROBERT HEARLE

Robert Hearle came to the University of Maryland in 1970 after working as a research chemist. While at Maryland he taught in the Chemistry and Education Departments, assisted in supervising student teachers in science, and was part of the IAC development team. Bob is now teaching in the Prince George's County, Maryland, school system. His special fields of interest include analytical and organic chemistry and computer-assisted instruction, including the development of a computer-managed independent study program.

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Contents

INTRODUCING *FORM AND FUNCTION* 1

Special Features in the Student Module 1
Managing the Laboratory 2
Evaluating Student Performance 3
Module Concepts 3
Module Objectives 5

TEACHING *FORM AND FUNCTION* 14

ORGANIC CHEMISTRY 14

O-1 A Vital Force? 14
O-2 Diversity of Organic Molecules 15
O-3 Carbon's Covalent Bonds 15

HYDROCARBONS 16

O-4 Energy: From the Sun to You 17
O-5 Fossil Fuels: Stored Organic Energy 18
O-6 Energy Plus Problems 18
O-7 The Single-Bonded Alkanes 18
O-8 Straight-Chain Molecular Models/*Miniexperiment* 19
O-9 Branched-Chain Molecular Models/*Miniexperiment* 21
O-10 Comparing Properties/*Miniexperiment* 21
O-11 Fuels: How Well Do They Burn? 22
O-12 Separating Hydrocarbons 23
O-13 Fractional Distillation/*Experiment* 24

REACTIONS OF HYDROCARBONS 28

O-14 How Strong the Bond That Binds 28
O-15 Chains and Rings 29
O-16 The Benzene Ring 30
O-17 Reactions of Hydrocarbons/*Miniexperiment* 31
O-18 Fused Rings: Bigger but Not Better 31
O-19 Molecules with a Bang 32

ALCOHOLS: OXIDIZED HYDROCARBONS 33

O-20 Oxidation and Reduction 33
O-21 Methyl and Ethyl: Their Properties 34
O-22 Another Type of Bonding 35
O-23 Functional Groups: Focus of the Matter 35
O-24 Fermented and Distilled Alcohols 36
O-25 Comparing Solubilities/*Experiment* 36
O-26 Polyalcohols 37

POISONS AND CHEMICAL WARFARE 38

O-27 Tears and More Tears 38
O-28 Alkylating Agents 39
O-29 Nerve Gases 39
O-30 Chemical Warfare in the Animal World 40

ALDEHYDES AND KETONES 41

O-31 The Carbonyl Clan 41
O-32 Carbonyl Chemistry and the Millipede 42
O-33 The Bombardier Beetle 43

PESTICIDES AND SEX ATTRACTANTS 44

O-34 Insecticides: Chlorinated Hydrocarbons 45
O-35 Chlorinated Hydrocarbon Problems 46
O-36 Ban All Insecticides? 47
O-37 Sex Attractants: An Alternative 48

ESTERS AND ACIDS 51

O-38 Preparation of Esters/*Experiment* 51
O-39 Organic Acids 53
O-40 Synthesis of Aspirin/*Experiment* 54
O-41 Soaps and Detergents 56
O-42 Preparation of Soap/*Experiment* 57
O-43 Maintaining the Cycle 58

ORGANIC BASES: THE AMINES 59

O-44 Ammonia's Offspring 59
O-45 Molecular Nitrogen 61

POLYMERS: THE LINKING OF MOLECULES 63

O-46 The Making of Macromolecules 63
O-47 From Monomer to Polymer 64
O-48 Synthesis of Nylon 66/*Experiment* 64
O-49 Properties of Polymers 65
O-50 Natural and Synthetic Polymers 67
O-51 Mirror Image Molecular Models/*Experiment* 67

PHOTOCHEMISTRY: LIGHT AND HEAT 70

O-52 Cold Light: Its Sources 70
O-53 Chemiluminescence of Luminol/*Experiment* 70
O-54 Cold Light: Its Uses 71
O-55 Chemistry of Vision 71
O-56 Photochemical Reaction/*Experiment* 72

DRUGS: FROM ASPIRIN TO HALLUCINOGENS 74

O-57 Let's Start with Aspirin 75
O-58 Alkaloids 75
O-59 Hallucinogens: The "Dream Makers" 76
O-60 Marijuana: Psychoactive Plant 76
O-61 Stimulants 76
O-62 Narcotics: Analgesic but Addictive 77
O-63 Barbiturates: The Synthetics 77

SUMMING UP 78

APPENDIX 80

Safety 80
Module Tests 81
  Knowledge-Centered Module Test 82
  Skill-Centered Module Test 85
Materials List 87
Index 89
Table of International Relative Atomic Masses 90
Periodic Table of the Elements 91

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Introducing Form and Function

The module, *Form and Function: An Organic Chemistry Module,* introduces the diverse field of organic chemistry—but in a nontraditional fashion. In the IAC presentation of organic chemistry, the authors have chosen to stress the concept of the functional group and illustrate its structural appearance, properties, and a few of its basic reactions. This is done through an investigation of compounds such as alcohols, aldehydes, ketones, esters, acids, and amines. Nomenclature is discussed briefly. Depending on the abilities of your students, you may wish to expand the topic of nomenclature with the help of Appendix II in the student module.

The approach to laboratory experiments gives students the opportunity to investigate for themselves the properties of organic compounds. They will make aspirin, produce a nylon polymer, make soap, synthesize flavorful esters, and conduct an experiment that mimics the actual chemistry involved in human vision.

The module allows for frequent class-teacher interaction. As students move along in their study of organic chemistry, they will consider the relevant and controversial topics of drugs, chemical warfare, pollution, energy problems, pesticides, and the use of synthetic materials in increasing amounts. Collecting current newspaper, magazine, and journal articles will make it easy to keep the topic of organic chemistry relevant and alive, as well as to make it possible for you to present the latest available information.

This module will present many new and fascinating ideas for your students, allowing them a deeper understanding of many topics they read about and experience daily. They will gain an introduction to the many facets of organic chemistry and will enjoy learning chemistry.

Special Features in the Student Module

Metric System Le Système Internationale (SI) is used throughout the IAC program. As you work with this module, you may wish to review some points of the metric system as presented in *Reactions and Reason: An Introductory Chemistry Module* (see section *A-8* and *Appendix II*). There is a metric units chart in the appendix of the *Reactions and Reason* student module that students can easily refer to.

Time Machine A feature we call the *Time Machine* appears in the IAC modules in order to show chemistry in a broader context. For some students this may provide a handle on particular aspects of chemistry by establishing the social-cultural-political framework in which significant progress has been made in chemistry. Students may enjoy suggesting other events in chemistry around which to create *Time Machines* of their own.

Cartoons A popular feature of the IAC program is the use of chemistry cartoons. These cartoons give students a chance to remember specific points of chemistry in another important way—through humor. Suggest that your students create other chemistry cartoons for their classmates to enjoy.

Safety Laboratory safety is a special concern in any chemistry course. In addition to including safety discussions and guidelines in the appendix of each student module and teacher's guide, experiments have been developed in a way designed to eliminate potentially dangerous chemicals and procedures. Moreover, each experiment that might present a hazard—such as fumes, corrosive chemicals, or the use of a flame—has been marked with a safety symbol to alert students and teachers to use added, reasonable caution. Caution statements, in bold type, also appear in experiments to specifically instruct the student on the care required.

Selected Readings Articles and books that tie in with the topics discussed in the IAC program have been listed in the appendix of the student module as well as at the end of each section in the teacher's guide. Encourage your students to use this section. You may wish to suggest other material that you yourself have found interesting and enjoyable.

Illustrations and Photographs The module is extensively illustrated to provide relevant and stimulating visual material to enable students to relate chemistry to everyday life, as well as to provide material for provocative discussion. In using some of these illustrations, it is not the intention of IAC to endorse any particular product or brand, but only to relate chemistry to life outside the classroom. As you proceed through each section, encourage students to collect, display, and talk about photos and illustrations that will provoke further discussion.

Questions, Problems, and Exercises Questions are naturally built into the narratives and the laboratory experiments. These are not planned as tests. IAC is designed so that mastery of the content and skills can be achieved through the repeated reinforcement of ideas and procedures encountered as a student progresses through the various modules. (Also see *Evaluating Student Performance* for additional information on evaluation and evaluation items for this module.)

Managing the Laboratory

In the teacher's guide, hints and suggestions are given for managing each experiment in the laboratory. Share as many of these hints as possible with your students to allow them to participate fully in successful laboratory management. Make sure that you rotate assignments so that each student has a chance to experience this type of participation.

Preparations and Supplies Student aides can be helpful in preparing solutions, labeling and filling bottles, cleaning glassware, and testing experiments. Each experiment has been classroom tested, but you should try each experiment to determine any revisions necessary to meet the special needs of your situation or that of your students.

Cleaning Up Involve your students in putting away equipment, washing up glassware, and storing material for the next time it is to be used. Taking care of equipment is part of the responsibilities we seek to foster.

Laboratory Reports and Data Processing Recording data and preparing reports on laboratory experimentation are important skills in all science courses and, of course, are part of the IAC program. Although you may have your own methods of student reporting, some of the suggestions that IAC teachers have found successful have been included for your consideration.

It is helpful for students to keep a laboratory notebook. A quadrille-ruled laboratory notebook with a sheet of carbon paper allows a student to produce two data sheets and copies of the report summary. Each page can be permanently retained in the notebook, and the duplicate copy can be submitted for evaluation or tabulation.

You will find it helpful if data summaries, including all written observations, are submitted at the end of the laboratory period, even though the calculations and/or questions are not due until a later date.

You will then be able to assemble a summary of all student results for a particular investigation on the chalkboard or on an overhead transparency. Such data permit useful discussion on determining a "best" value through a median or mean value, a histogram, or through some other visual report of overall student results.

A realistic view of laboratory work suggests that in the most fundamental sense there are no wrong laboratory results. All students obtain results consistent with the particular experimental conditions (either correct or incorrect) they have established. Because careful work will yield more precise results, encourage each student to take personal pride in experimental work. If students disagree on a result, discuss the factors that might account for the difference. A student who provides a thoughtful analysis of why a particular result turned out to be "different" (incomplete drying, a portion of the sample was spilled, etc.) deserves credit for such interpretation.

Laboratory Safety The IAC program introduces many new laboratory procedures and activities to students. To use the IAC program safely you should become thoroughly familiar with all student activities in the laboratory. Do all the experiments and carry out all the demonstrations yourself before presenting them to your class. We have tested each experiment and have suggested the use of chemicals that provide the least chance of causing a safety problem in the laboratory. The teacher's guide has many suggestions to help you provide your students with safe laboratory experiences. Have the students read *Appendix I: Safety*. Then conduct a brief orientation to laboratory safety before the students encounter their first laboratory experience in each module. Review, when necessary, and discuss precautions and safety each time a safety symbol appears in the student text. In addition, the *Suggested Readings* in the teacher's guide of *Reactions and Reason* lists safety manuals that give detailed instructions on the handling of hazardous chemicals, disposal of chemicals, and general laboratory safety.

Materials for IAC In light of increasing costs for equipment and supplies, as well as decreasing school budgets, we have tried to produce a materials list that reflects only the quantities needed to do the experiments with minimal surplus. Thus, the laboratory preparation sections contain instructions for only a 10 to 20 percent surplus of reagents. Add enough materials for student repeats and preparation errors.

Evaluating Student Performance

There are many ways of evaluating your students' performances. One of the most important forms of evaluation is observing your students as they proceed through the IAC program. IAC has developed skill tests and knowledge tests for use with this module. These test items have been suggested and tested by IAC classroom chemistry teachers. You are encouraged to add these to your own means of student evaluation. The module tests are at the end of the teacher's guide.

In addition to the problems and questions incorporated in the student module text and illustration captions, there are suggested evaluation items at the end of each module section in the teacher's guide. Answers to all of the evaluation items are included to help you in your classroom discussion and evaluation.

Module Concepts

ORGANIC CHEMISTRY

- Organic chemistry is the study of compounds that contain carbon.
- There is a tremendous number and variety of organic compounds that are made possible because of carbon's ability to form covalent bonds with itself and other atoms.
- Organic compounds are grouped into classes according to similarities in their functional groups, which result in similarities of physical and chemical properties.

HYDROCARBONS

- Hydrocarbons are organic compounds containing only hydrogen and carbon.
- Most hydrocarbon compounds are derived from living organisms—both past and present.

- Alkanes, or saturated hydrocarbons, are used widely as fuels.
- Use of hydrocarbons as fuels in internal combustion engines presents many problems to the environment.
- Alkanes are generally separated by fractional distillation, a separation technique based upon differences in boiling points.

REACTIONS OF HYDROCARBONS

- Alkenes and alkynes, also known as unsaturated hydrocarbons, contain double and triple bonds between carbon atoms. These bonds are weaker (more reactive) than single bonds between carbon atoms.
- Alkanes usually react by substitution—the replacement of a hydrogen atom by another atom.
- Alkenes and alkynes generally react by the addition of other atoms to the multiple bond.
- Hydrocarbon compounds may form rings as well as chain and branched molecules.
- The benzene ring, which contains alternating double bonds, is a stable molecular structure that usually reacts by substitution rather than by addition.
- Benzene rings that are fused together form a class of compounds known as the aromatic compounds.
- Organic compounds that contain nitro (NO_2) or nitrate (ONO_2) groups may be explosive.

ALCOHOLS: OXIDIZED HYDROCARBONS

- Alcohols are organic compounds that contain a hydroxyl group.
- Alcohols are in the next higher oxidation state above the hydrocarbons.
- Oxidation is the addition of oxygen and/or loss of hydrogen from a molecule.
- Reduction is the addition of hydrogen and/or loss of oxygen from a molecule.
- Alcohols have higher boiling points and are more water soluble than hydrocarbons because of hydrogen bonding.
- Functional groups provide the basis for classification of organic compounds.
- A functional group has a characteristic structure and reactivity that is different from other functional groups.

POISONS AND CHEMICAL WARFARE

- Some chemical warfare agents may be classified as alkylating agents, nerve gases, or lacrimators.
- Many chemical warfare agents are organic compounds containing nitrogen, sulfur, and chlorine.
- There are useful applications of poisonous chemical compounds.
- Many poisons affect the chemistry of the body thereby producing harmful results.
- Many animals produce chemical poisons that they use as self-defense mechanisms.

ALDEHYDES AND KETONES

- Aldehydes and ketones contain structures known as carbonyl groups—carbon atoms doubly bonded to an oxygen atom.
- The carbonyl group represents a higher oxidation state of carbon than do the alcohols.
- Aldehydes and ketones can be synthesized from alcohols by oxidation of primary and secondary alcohols.
- Aldehydes and ketones can be converted to the alcohols from which they were derived by reduction reactions.
- The carbonyl group undergoes addition-type reactions.
- Many insects use carbonyl-containing compounds as self-defense mechanisms.

PESTICIDES AND SEX ATTRACTANTS

- Insecticides classified as chlorinated hydrocarbons are stable (they do not biodegrade easily) and, therefore, build up in the environment.
- Chlorinated hydrocarbons are often toxic to certain living organisms.
- Insecticides not only kill insects, but they are often harmful and sometimes lethal to other forms of life.
- Pheromones are produced naturally and are used by insects as chemical messages and sex attractants.
- As a form of insect control, pheromones can be used to lure insects of certain species for selective control procedures.

ESTERS AND ACIDS

- Esters and carboxylic acids contain a carbon atom that is doubly bonded to one oxygen atom and singly bonded to another oxygen atom to form a structure known as a carboxyl group.

- The carbon atom in a carboxyl group is in a higher state of oxidation than the carbon atom found in the carbonyl group of aldehydes and ketones.
- Many esters are used in the food and the cosmetic industries as flavorings and fragrances.
- Carboxylic acids are usually weak acids in comparison to inorganic acids.
- The cleaning ability of soaps and detergents is related to their molecular structures.
- Detergents, which are substitutes for soaps, have contributed to the pollution of water by aiding eutrophication.
- Many organic compounds may be recycled, that is, the compounds may be broken down by living things into simpler molecules which can then be resynthesized into other compounds by organisms.

ORGANIC BASES: THE AMINES

- Organic amines contain nitrogen and are related to the inorganic compound ammonia.
- Like ammonia, the amines are weak bases.
- The source of nitrogen in organic compounds is molecular nitrogen (N_2), which is converted to ammonia by a variety of bacteria.
- Molecular nitrogen is converted into nitrites and nitrates, which, in turn, are reduced to ammonia in plant tissues.

POLYMERS: THE LINKING OF MOLECULES

- Polymers are large organic molecules composed of many smaller molecules called monomers.
- Most present-day synthetic fibers are actually organic polymers.
- Many organic polymers, such as starches and cellulose, are produced by nature.
- Polymer properties are related to the properties of the monomer(s) of which they are composed.
- Molecules with different three-dimensional (geometrical) arrangements of groups with respect to a double bond in the carbon skeleton are called *cis-trans* isomers.
- Different *cis-trans* isomer compounds, such as natural rubber and gutta-percha, have different properties.
- Mirror-image isomers arise from the presence of asymmetric carbon atoms.

PHOTOCHEMISTRY: LIGHT AND HEAT

- Chemiluminescent reactions are unusual in that they release light but not heat.
- Many organisms have the ability to bioluminesce.
- The process of human vision is the result of a photochemical reaction.
- Thin-layer chromatography is an analytical technique used to separate and identify the components of a mixture.

DRUGS: FROM ASPIRIN TO HALLUCINOGENS

- Drugs encompass a wide range of organic compounds that may be classified according to structure and function in the human body.
- Many drugs (containing at least one nitrogen atom) are classified as alkaloids, which are naturally occurring compounds found in plants.
- Hallucinogenic compounds act on the central nervous system.
- Narcotic drugs are classified as analgesics—pain killers—and may be addictive.
- Many organic compounds that act as drugs or hallucinogens in the human body do so by mimicking natural body chemicals.

Module Objectives

We have attempted to group module objectives in three broad categories: concept-centered, attitude-centered, and skill-centered. The categories are not mutually exclusive; there is considerable overlapping. The conditions for accomplishing each objective are not given, since they can easily be found in the respective sections in the module. Note also that concept and skill objectives are more specific than those in the affective domain. It is very difficult to classify objectives in this way, but we have been encouraged to do so by classroom teachers, who have helped in this difficult task.

The objectives identified here should provide you with a useful starting point in clarifying your own goals in teaching this module. We encourage you to identify alternative objectives, using this list as a point of departure. *Evaluation Items* to help assess the stated objectives are included after each major section in this guide. In addition, module tests for knowledge and skill objectives are located in the appendix of this teacher's guide.

ORGANIC CHEMISTRY

Concept-Centered Objectives	*Attitude-Centered Objectives*	*Skill-Centered Objectives*
O-1 ● Organic compounds are derived from living and nonliving sources. **O-2** ● Identify the bond type found in most organic compounds as a covalent bond. **O-3** ● Identify single, double, and triple bonds, and relate these bonds to the number of electron pairs shared.	● Relate the usefulness and importance of organic compounds to everyday life. ● Realize the great diversity of organic compounds.	

HYDROCARBONS

Concept-Centered Objectives	*Attitude-Centered Objectives*	*Skill-Centered Objectives*
O-4 ● Using an equation, explain the formation of organic compounds from inorganic compounds, such as occurs in photosynthesis. **O-5** ● Relate the formation of fossil fuels to stored energy resources. ● Identify the combustion products of hydrocarbons. **O-6** ● Recognize that the combustion of hydrocarbons containing contaminants produces pollution. **O-7** ● Identify simple alkanes by structure and molecular formula.	● Recognize that the number of possible isomers increases as the carbon number increases. ● Become aware of the contribution of fossil fuels to air pollution. ● Discuss the relationship of problems of the combustion of gasoline to environmental problems.	**O-7** ● Draw structural formulas of simple hydrocarbons. **O-8** ● Make ball-and-stick models of simple, straight-chain hydrocarbons. **O-9** ● Make ball-and-stick models of branched-chain hydrocarbons. ● Demonstrate understanding of isomerism through the use of drawings or models. **O-10** ● Distinguish an organic compound from an inorganic compound by means of its combustibility and melting point.

Concept-Centered Objectives	*Attitude-Centered Objectives*	*Skill-Centered Objectives*

HYDROCARBONS

O-8, 9
- Explain what isomerism is and its importance in increasing the number of organic compounds.
- Relate changes in physical properties, such as boiling point, with changes in molecular structure.

O-11
- Relate the octane number of a gasoline to its hydrocarbon composition.
- Identify technological and environmental problems related to the internal combustion engine.

O-12
- Relate change in physical properties, such as boiling point, to change in molecular weight of hydrocarbons.
- Explain how fractional distillation separates a mixture of compounds having different boiling points.

O-13
- Perform a fractional distillation to separate a mixture.

REACTIONS OF HYDROCARBONS

O-14
- Relate reactivity of bonds to degree of bond unsaturation.
- Recognize an addition or a substitution reaction from a given equation.
- Identify, by structure, the compounds most likely to undergo substitution and addition reactions.

O-15
- Differentiate between ring and chain hydrocarbons given their structures.

- Recognize the diversity of benzene compounds and the special stability of the benzene ring.
- Appreciate the wide range of influence of aromatic and explosive compounds on our way of life.
- Be conscious of the importance of disposing of organic waste by methods which avoid environmental pollution.

O-17
- Identify saturated compounds as compared with unsaturated compounds, based on their reaction with $KMnO_4$.
- Predict reactivity of compounds given their structure, and then verify the predictions by experimentation.
- Demonstrate safe handling of volatile chemicals and proper disposal of organic chemical wastes.

REACTIONS OF HYDROCARBONS

O-16

- Identify benzene and related aromatic hydrocarbons given their structures.

O-18

- Identify fused aromatic rings given their chemical structures.

O-19

- Identify the elements present in organic explosives which are responsible for their explosive nature.

ALCOHOLS: OXIDIZED HYDROCARBONS

O-20

- Relate oxidation-reduction to loss or gain of oxygen.
- Identify the alcohol functional group.

O-21

- Recognize the similarities in structures and the differences in properties of methyl and ethyl alcohols.

O-22

- Explain the comparatively higher boiling point of an alcohol over that of its related hydrocarbon as a function of hydrogen bonding.

O-23

- Recognize the functional group as the site of chemical reactivity in organic compounds.
- Identify, name, and classify functional groups.

- Discuss the contribution of methyl and ethyl alcohols to modern society.
- Understand how a knowledge of solubility principles can be useful in the home.

O-22

- Construct ball-and-stick models of water, methyl alcohol, and ethyl alcohol to demonstrate hydrogen bonding.

O-25

- Determine solubility of common materials in water and organic solvents.
- Classify a compound as polar or nonpolar, based on its solubility in water and other solvents.

Concept-Centered Objectives	*Attitude-Centered Objectives*	*Skill-Centered Objectives*
ALCOHOLS: OXIDIZED HYDROCARBONS		
O-24 ● Recognize the uses of the fermentation process. **O-25** ● From knowledge of their molecular structures, predict the solubility of solvents in each other. ● Predict the solubility of organic and inorganic compounds in different solvents. **O-26** ● Classify di-, tri-, and polyhydroxy alcohols given their structures.		
POISONS AND CHEMICAL WARFARE		
O-27 ● Explain the action of lacrimators on the human body. **O-28** ● Explain the action of alkylating agents on human protein. ● Identify medical applications of mustard compounds. **O-29** ● Describe the mode of action of nerve gases which makes them effective poisons. **O-30** ● Describe various chemical mechanisms used in the animal world for self-defense.	● Acknowledge that the human body is made up of chemical compounds that can be altered by reactions with other chemical compounds. ● Discuss some of the peaceful uses to which several chemical warfare agents have been applied. ● Appreciate some of the sophisticated chemical defense mechanisms of animals.	

Concept-Centered Objectives	*Attitude-Centered Objectives*	*Skill-Centered Objectives*
ALDEHYDES AND KETONES		
O-31 ● Identify a carbonyl group and relate its appearance to aldehydes and ketones. ● Differentiate alcohols from aldehydes and ketones. ● Recognize how alcohols may be converted to aldehydes by an oxidation reaction.	● Gain an appreciation for the number and uses of aldehydes and ketones. ● Begin to perceive what organic chemical synthesis is and how it occurs by understanding the chemical relationship of alcohols, aldehydes, and ketones.	
O-32, 33 ● Relate the role of carbonyl compounds to insect defense mechanisms. ● Explain reversible reactions using oxidation-reduction as an example.		
PESTICIDES AND SEX ATTRACTANTS		
O-34 ● Recognize chlorinated hydrocarbons by their structures. ● Using chlorinated hydrocarbons as examples, describe the process by which these pesticides accumulate within living things and their persistence within the environment.	● Realize that most insects are valuable to human welfare. ● Take positions for or against the use of DDT and other insecticides. ● Debate the complex entanglements of applied chemical technology versus environmental protection.	
O-35 ● Describe some uses of noninsecticide chlorinated hydrocarbons and explain their effect on the environment.		
O-36 ● Discuss the effects of banning all insecticides.		
O-37 ● Compare the consequences on the environment of using sex attractants as opposed to using insecticides to control insect pests.		

Concept-Centered Objectives	*Attitude-Centered Objectives*	*Skill-Centered Objectives*
	ESTERS AND ACIDS	
O-39 • Recognize the esterification reaction. • Identify an organic acid and an ester by their functional groups. • Identify common substances that are organic acids or esters. • Compare the strengths of organic and inorganic acids. • Recognize the effect of lengthening the *R* group on the solubility of acids and esters in water. **O-41** • Explain how a soap or a detergent works. **O-42** • Describe the process in which detergents can cause environmental pollution. **O-43** • Recognize the significance of recycling chemical elements to aid in the prevention of environmental pollution.	• Appreciate the variety of uses of esters and acids and their importance to our lives. • Discuss the benefit of using modern detergents versus their impact on the environment.	**O-38** • Demonstrate the preparation of a specific ester by choosing the correct reactants needed for the synthesis. **O-40** • Synthesize an aspirin sample. • Test aspirin samples for solubility, melting point, and impurities. **O-42** • Demonstrate the preparation of a soap.
	ORGANIC BASES: THE AMINES	
O-44 • Identify the amine functional group. • Differentiate primary, secondary, and tertiary amines. • Compare invert soaps with commercial soap. **O-45** • Relate the nitrogen and the carbon cycles to the recycling concept. • Explain how bacteria convert N_2 to NH_3. • Discuss the forms in which living things excrete nitrogen-containing compounds.	• Gain appreciation for the widespread use of nitrogen-containing compounds. • Understand that humans are an integral part of the chemistry of the environment and, as such, are dependent upon the continuation of carbon and nitrogen cycles. • Appreciate the significance of nitrogen compounds in a historical perspective.	

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Concept-Centered Objectives	*Attitude-Centered Objectives*	*Skill-Centered Objectives*
POLYMERS: THE LINKING OF MOLECULES		
O-46 • Determine the molecular weight of a polymer given its formula and the molecular weight of its monomers. **O-47** • Given the formula of a simple monomer, write the formula for the resulting polymer. • Distinguish between monomer, polymer, and copolymer. **O-49** • Relate the physical property of a polymer to that of its monomer(s). **O-50** • Compare the properties of natural and synthetic polymers. **O-51** • Relate line drawings of mirror-image isomers to three-dimensional structures.	• Argue for or against the substitution of synthetic materials for natural products. • Realize that some scientific discoveries can be the results of chance and an alert mind. • Appreciate the vast research effort that goes into creating a single chemical product. • Discuss the effects that polymers have had on shaping our current way of life.	**O-48** • Synthesize a simple polymer—nylon 66. **O-51** • Construct models that demonstrate mirror-image isomerism.
PHOTOCHEMISTRY: LIGHT AND HEAT		
O-52 • Distinguish between chemiluminescence and other forms of light production in terms of heat and light emission. • Provide examples of common organisms that exhibit bioluminescence. **O-55** • Recognize the chemistry involved in human vision. • Identify *cis-trans* isomers given their structures. **O-56** • Explain the principle by which thin-layer chromatography works as a chemistry separation technique.	• Recognize the fact that many living organisms can produce light. • Gain appreciation for the fact that our vision is possible because of a complex series of chemical reactions.	**O-53** • Demonstrate chemiluminescence using luminol. **O-56** • Diagram the differences between *cis-trans* isomers. • Use thin-layer chromatography to separate the components of a mixture. • Calculate R_f values for different components following their separation by thin-layer chromatography.

DRUGS: FROM ASPIRIN TO HALLUCINOGENS

Concept-Centered Objectives	*Attitude-Centered Objectives*	*Skill-Centered Objectives*
O-57 ● Describe the mode of action of sulfanilamide against bacterial infection. **O-58** ● Distinguish among the various classes of drugs. **O-59** ● Identify the indole ring commonly found in many hallucinogens. ● Compare the structures of compounds that act as hallucinogens with the structures of compounds occurring naturally in the human body. **O-60** ● Identify the active ingredient of marijuana, and discuss its effects on the human body. **O-61** ● Identify stimulants, their derivations, and their uses. **O-62** ● Identify examples of narcotics, their derivations, and their effects on the body. **O-63** ● Recognize examples of barbiturates and their modes of action.	● Discuss the vital role of drugs in today's society. ● Understand that many drugs are useful in limited doses and harmful in excess. ● Discuss the use of drugs from an historical perspective. ● Recognize that drugs are accepted by the human system because they mimic already present compounds.	

Teaching Form and Function

Organic Chemistry

Why are the compounds of carbon classified within a separate discipline, *organic chemistry*? The introductory section of the student module helps to explain this as it outlines the basic characteristics of carbon. You can reinforce this by asking students to compile a list of items that are made from organic materials. Start by having the students look over the photographs on page 1 of the student module. Continue with the discussions on page 2, and then have the students conclude their lists. You may wish to extend this discussion by asking students to come up with another list of items that are made from inorganic compounds. Briefly discuss the lists but do not give any conclusive answers. Ask students to keep the lists in their notebooks for the time being, and after they have completed the module, have them go back and review the lists. This might be an activity for a concluding discussion in the Summary section at the end of the module.

Discuss with your students the illustrations in the margin on page 2 concerning the versatility of carbon as an element and its bonding potential. During this discussion, you may wish to refer to the *Periodic Table of the Elements* on the inside back cover of the module.

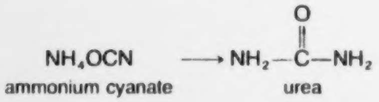
Discuss the properties of graphite and diamond using the photo on page 2. Bring in a sample of graphite and examine its properties. Compare the structural bonding of both forms of carbon using the illustrations in the margin on page 2 of the student module, and point out that the structure of a substance has a direct relationship to its properties. Diamond is a crystal made of interconnected carbon atoms whereas graphite consists of sheets of carbon atoms piled on top of one another. After discussing the structures in the marginal illustration *Two Forms of Pure Carbon*, you may wish to have your students check on the uses of both graphite and diamonds and the history of the production of synthetic diamonds and their uses.

Students might refer to *Communities of Molecules: A Physical Chemistry Module* for more information and illustrations on network crystals of carbon and diamonds.

O-1 A VITAL FORCE?

The origin of the terms *organic* from a living thing and *synthesis* are discussed briefly in this section. Stress that carbon-containing compounds are organic regardless of whether they originate from living things or from laboratory synthesis. In buying vitamin C, for instance, organic vitamin C from rose hips is identical to synthetic vitamin C (ascorbic acid) except for the price.

The vital force theory, believed by most scientists as recently as 150 years ago, maintained that chemical compounds composed of living matter could be produced by living organisms only and not synthesized in laboratories. During the first half of the nineteenth century, however, a number of scientists obtained experimental results to the contrary. In 1828 a German chemist, Friedrich Wöhler, synthesized urea, a natural chemical in urine, by heating ammonium cyanate, a well-recognized inorganic salt.



$$NH_4OCN \longrightarrow NH_2{-}\overset{\overset{\displaystyle O}{\|}}{C}{-}NH_2$$

Marcellin Berthelot continued this type of research and also synthesized organic compounds from inorganic compounds. It was Berthelot who finally disproved the "vital force theory" (see *Time Machine*, student module page 3). Students who are interested in the history of chemistry may wish to explore the controversy surrounding the vital force theory at greater length. Encourage them to check their library research center for more information on this and the origins of organic chemistry. Using the *Time Machine* on page 3, discuss briefly with your students that the final disproving of the vital force theory underlines the notion that organic chemistry in its modern form is a rather young area of chemistry.

An interesting example of an organic compound that has an inorganic isomer can be found in the case of urea and ammonium cyanate. (The concept of isomerism will be discussed later in sections *O-8*, *O-9*, and *O-10*.) A more recent development shows the unique chemical relationship between these two compounds, which has been documented in the treatment of sickle-cell anemia. This disease arises from a genetic defect in the hemoglobin molecule in red blood cells. As a result, the hemoglobin molecule becomes deformed (its shape changes from spherical to ellipsoidal) when oxygen is present in the cells in low concentrations. Because of this change in shape, the hemoglobin tends to crystallize in the red blood cells, deforming the cells, and making them less useful for oxygen transport. Urea reverses this process by denaturing the hemoglobin and allowing it to resume its normal shape. This requires that large quantities of urea be given to sickle-cell patients. Urea in large quantities is toxic to human beings and, therefore, makes the treatment somewhat dangerous.

It occurred to one scientist that perhaps it was the action of the inorganic compound ammonium cyanate, formed from urea in the human body, that reversed the "sickling" of the red blood cells. This appears to be the case, since administration of small quantities of ammonium cyanate to people suffering from sickle-cell anemia alleviates the symptoms of this disease.

Interested students may wish to refer to *Molecules in Living Systems: A Biochemistry Module* and *Diversity and Periodicity: An Inorganic Chemistry Module* for more information on sickle-cell anemia. Other current articles on sickle-cell anemia may be available in your library resource center.

O-2 DIVERSITY OF ORGANIC MOLECULES

This section introduces some of the organic molecules in terms of size and shape. Students can compare one of the simplest compounds, methane, for instance, with the more complex compounds, vitamin A and β-carotene.

Discuss the different ways to represent (write) chemical compounds as noted in the illustration on page 3 of the student module. You may wish to use other examples of organic structures from the module in your discussion. Have your students compare the β-carotene and vitamin A structures presented on page 3 with those on page 104 (student module). Ask if they can note any differences and determine why one form might be preferred over the other. The structures on page 104 represent one shorthand method of presenting the information that an organic chemist needs to know about the structure of the compound.

The concept of *isomerism* is introduced briefly on page 4 of the student module. You may not wish to dwell on this topic at this time as it will be discussed later in the module.

End the discussion of this section by leading students to the realization that there are millions of known organic compounds and many more are being synthesized each year. In order to study these compounds, it is necessary to bring some order and organization to organic chemistry. Since compounds vary so much they must be grouped in some manner for use and study. Students may recall a discussion similar to this in *Reactions and Reason* where chemicals were grouped or classified. Similarly, organic chemists group compounds according to similar properties. Some of the groupings are listed at the end of section *O-2*. Students will discover, later in this module, that these groupings are called functional groups. Do not dwell on this topic, because it will be covered in much more detail as students progress through the different classes of organic compounds.

O-3 CARBON'S COVALENT BONDS

Review the concept of covalent bonding, referring to the carbon chain on page 4 and the table on page 2. Emphasize carbon's ability to bond with other carbon atoms, which accounts for the large number of organic compounds that exist and that can be synthesized. Extend your lesson by explaining how double and triple bonds represent the sharing of two or three pairs of electrons. You can use the structural formulas for vitamin A and β-carotene (page 3 of the student module) and ethylene and acetylene (page 24 of the student module) as examples of double- and triple-bonded compounds. Extend the lesson with examples and written practice until you feel your students have grasped the concept of covalent bonding sharing of electrons.

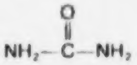
EVALUATION ITEMS

These are suggestions for evaluation items which you may wish to use with your students at various times during the preceding section. The correct answer to each question is indicated by shading.

1. What is the difference between an organic compound and an inorganic compound?

   Organic compounds contain the element carbon while inorganic ones do not.

2. The body excretes carbon in the form of carbon dioxide while nitrogen is excreted in the form of urea,

   $NH_2{-}\overset{\overset{O}{\|}}{C}{-}NH_2$

   found principally in urine. In 1828, a German chemist, Frederick Wöhler, synthesized urea by heating a well-recognized inorganic salt, ammonium cyanate (NH_4OCN). Explain how this could be used to challenge the vital force theory.

   The vital force theory said that organic compounds could only come from living sources, so the formation of an organic compound from nonliving sources is evidence that the theory does not hold, or is incorrect.

3. Name the different ways that an organic compound can be represented. Give examples. Tell why each example might be useful.

   Answers determined by teacher.

4. The type of bond found in organic compounds that allows for the great diversity of structures is:

   A. ionic
   B. covalent
   C. hydrogen
   D. polar

5. Select the compound below that contains a double bond:

   A. $CH_3CH_2CH_2CH_3$
   B. $CH_3CH{=}CHCH_3$
   C. $CH_3C{\equiv}CCH_3$
   D. $CH_3{-}CH_2{-}CH_3$

6. A single bond contains _B_ shared electron pair(s).

   A double bond contains _A_ shared electron pair(s).

   A triple bond contains _C_ shared electron pair(s).

   A. 2 B. 1 C. 3 D. 4

SUGGESTED READINGS

Bent, Henry. "The Tetrahedral Atom." *Chemistry*, December 1966, pp. 9–13.

Man-made Diamond. General Electric Company. (For a free copy, write to: 570 Lexington Avenue, New York, NY 10022.)

Maugh, T. H., 2d. "Unusual Structures Predicted for Carbon Compounds." *Science* 194:413. October 22, 1976.

Murray, Charles. "Man-made Diamonds." *Science Digest*, April 1973, pp. 88–90.

"Synthetic Diamonds." *Chemistry*, November 1970, p. 20.

SUGGESTED FILMS AND FILMSTRIP

Films:

Carbon and Its Compounds. Color, 16 minutes. Coronet Instructional Films, 65 E. South Water St., Chicago, IL 60601.

Man-made Diamond. Color, 11 minutes. General Electric Educational Films, Building 705, Corporations Park, Scotia, NY 12302.

The Modern Chemist—Diamond Synthesis. Color, 12 minutes. Sutherland Learning Association, 8425 W. Third Street, Los Angeles, CA 90048.

Filmstrip:

Chemistry. Four filmstrips and cassettes. *(Scientists and Their Work, What is Chemistry? Career Challenges: Herbicide Research, Career Challenges: Water Purification.)* Prentice-Hall Media, ServCode KC 2, 150 White Plains Rd., Tarrytown, NY 10591.
Views chemistry as a way of life by showing how scientists, presented with real-life problems, seek solutions through chemistry.

Hydrocarbons

You can look upon your teaching of the previous section as an introduction to hydrocarbons, the simplest of the organic compounds. Refer to the formulas for methane, β-carotene, and vitamin A as you discuss the definition of hydrocarbon—a compound that contains *only* hydrogen and carbon. With this in mind, ask your students to determine which previously discussed compounds are hydrocarbons. (Point out that vitamin A, carbon, diamond, and graphite are not hydrocarbons.)

Also ask your students to check their daily newspapers and magazines and bring in headlines and clippings that focus on the areas discussed in this section. A display of these will point up the relevance of organic chemistry to everyday life.

In studying the hydrocarbons, your students will consider the extensive ways in which this group of organic compounds has been incorporated into our lives. They will examine and trace the origins of fuels which contain stored chemical energy. They will also discuss the release of this energy to do work for us and the associated problems of pollution. Beginning in section *O-7*, students will review the concept of isomerism and gain an appreciation of the wide variety of hydrocarbon structures and their differing physical properties. As an application of this knowledge, students will conduct a simple fractional distillation experiment.

Some of your students may wish to write for further information and consumer booklets on the history and production of coal, gas, and petroleum and their products. These are a few of the free titles available from private companies and trade associations.

Coal Facts; The Bituminous Coal Story; Coal (reprint from *World Book*). National Coal Association, Coal Building, 1130 Seventh Street, N.W., Washington, DC 20036.

The Story of Natural Gas Energy; What Is a Gas? American Gas Association, 1515 Wilson Boulevard, Arlington, VA 22209.

Facts About Oil; Movies About Oil; Energy Conservation Experiments; Distillation Wall Chart. American Petroleum Institute, 2101 L Street, N.W., Washington, DC 20037.

The Story of Oil. Chevron U. S. A., Inc., 575 Market Street, San Francisco, CA 94105.

Students can also research these topics in their library resource center—coal and petroleum are usually included in every basic reference book that contains topics of scientific interest.

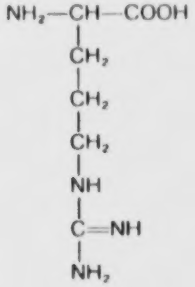
O-4 ENERGY: FROM THE SUN TO YOU

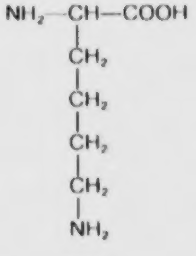
Begin the study of energy storage in hydrocarbon molecules with a discussion of how glucose is produced by green plants during photosynthesis. This is a means by which energy from the sun becomes available for use by all other living things. Discuss the photosynthesis equation on page 6 of the student module with the thought in mind that glucose (sugar) represents a chemical compound which has resulted from a process (photosynthesis) involving the conversion of light energy which has been converted to chemical energy. Draw CO_2 and H_2O on the chalkboard and show how these molecules combine to form a glucose molecule (see structural formula on page 6, bottom).

Glucose is one organic compound which is not a hydrocarbon. Ask your students to explain why this is so by examining the structural formula on page 6. To reinforce this, the following demonstration can be performed. **Caution:** *This is recommended as a demonstration because of the caustic effects of using concentrated sulfuric acid. Take necessary precautions.*

Demonstration Carefully add 10 cm^3 of concentrated sulfuric acid (H_2SO_4) to 10 g sugar in a beaker. Note the reaction. After it has stopped, ask students to interpret what the black deposit is. Put the molecular formula for sugar ($C_6H_{12}O_6$ *or* $C_{12}H_{22}O_{12}$) and water (H_2O) on the chalkboard. Ask students in what ratio would the hydrogen and oxygen atoms have to be removed from sugar in order to form the water they observed escaping from the beaker. (Answer: 2 to 1: hydrogen to oxygen). Use the glucose formula on page 6 to show where water molecules are removed, thus leaving a carbon residue.

Just as organic compounds such as protein are synthesized in nature, they also decompose to simpler molecules such as hydrocarbons. Relate this discussion to the formation of methane. To help students understand how a hydrocarbon is formed from decomposed protein, you may wish to draw the structural formulas of the amino acids arginine and lysine.


arginine


lysine

These amino acids decompose to putrescine and cadaverine respectively (structural formulas are given on page 7) resulting in the release of carbon dioxide and amine-containing compounds such as urea.

O-5 FOSSIL FUELS: STORED ORGANIC ENERGY

Ask your students what process is demonstrated in the equation on page 7 of the student module (combustion of methane). Discuss the by-products of this reaction. What types of energy are released from the burning of methane (heat, light—forms of kinetic energy or energy required to do work)? Recall from section *O-4* that the hydrocarbon methane was a result of the decomposition of molecules from once-living organisms. Examine the cyclical relationship between this equation and that for photosynthesis in which we see carbon dioxide and water converted into glucose (energy storage) and the production of carbon dioxide and water from the burning of methane (energy release).

O-6 ENERGY PLUS PROBLEMS

Discuss the production of energy fuels using the photos on student module page 9. Ask students to look over their collection of recent news articles and suggest some current problems connected with petroleum, natural gas, coal, and their by-products. As you discuss the photographs and the text material on pages 10 and 11, explain that there are impurities in petroleum, which contain nitrogen and sulfur, the residue of the decomposition of certain organic compounds to hydrocarbons. When nitrogen containing compounds are burned, they produce oxides of nitrogen: NO, NO_2, and N_2O_4. These are irritating to the eyes and inhibit breathing.

Review the reactions on sulfur pollution and ask if anyone is able to suggest some method of "utilizing" this pollution. Interested students may wish to discuss the chemical reactions cited on page 10 showing the development of a system which can turn SO_2 pollution into sulfuric acid. A visit to an electricity-generating plant or coal-burning plant may provide insights regarding Federal government regulations on the use of "scrubbers" on industrial stack exhaust pipes. Have an interested student write to the Environmental Protection Agency, 401 M Street SW, Washington, DC 20460, inquiring about antipollution laws and the "acceptable" levels of various pollutants in our atmosphere. They may also want to write the American Lung Association, 1740 Broadway, New York, NY 10019, for information regarding various lung diseases caused by pollution.

The combustion of fossil fuels also releases many metals into the atmosphere; two major fossil fuels are vanadium and nickel. The effects of these metals on living organisms are still not completely understood. Students may wish to check recent periodicals for additional information on metal pollution in the atmosphere. Some interested students may also wish to prepare a photo display and discussion on additional energy pollution problems similar to the ones illustrated on pages 10 and 11.

O-7 THE SINGLE-BONDED ALKANES

The alkanes, often called saturated hydrocarbons, are a useful group of organic compounds. Discuss the names of the illustrated alkanes, the meaning of the *-ane* suffix which indicates only single covalent bonds between carbon atoms (saturation), and their uses as fuels. Depending upon the inclinations of your students, you may briefly explore the history of the alkane series which is also called the paraffin series (Latin *parum*, little; *affinis*, affinity). Have students try to derive the general formula (using the structural formulas on page 12) which states the proportion of carbon to hydrogen atoms in different alkanes (C_nH_{2n+2}).

The alkanes form what is called a homologous series in which succeeding members of a series are similar in structure but differ in formula by the addition of a given group. In the case of the alkanes, new series members result from the addition of $(CH_2)_n$ when $n = 1, 2, 3, 4, \ldots$ (all whole numbers).

You may wish to mention two other classes of hydrocarbons, alkenes and alkynes, which consist of compounds that are unsaturated and contain double and triple carbon-carbon bonds respectively. Write the following formulas on the board and have the students derive the general formulas for both the alkene and the alkyne series.

ALKENES

$H_2C{=}CH_2$ ethylene (C_2H_4)	$CH_3CH{=}CH_2$ propylene (C_3H_6)
$CH_3CH_2CH{=}CH_2$ 1-butene (C_4H_8)	$CH_3CH{=}CHCH_3$ 2-butene (C_4H_8)

ALKYNES

$HC{\equiv}CH$ ethyne (acetylene) (C_2H_2)	$CH_3C{\equiv}CH$ propyne (C_3H_4)
$CH_3CH_2C{\equiv}CH$ 1-butyne (C_4H_6)	$CH_3C{\equiv}CCH_3$ 2-butyne (C_4H_6)

The general formula for alkenes is C_nH_{2n} and C_nH_{2n-2} for alkynes.

MINIEXPERIMENT
O-8 STRAIGHT-CHAIN MOLECULAR MODELS

This activity will help students become acquainted with model building and provide further insight into the diversity of the hydrocarbon structure. In addition, it will introduce the concept of chain and branch structures.

Concepts In doing this miniexperiment, a student will encounter these important ideas*:

- There is a great diversity of structure of organic compounds because carbon can form single bonds with other carbon atoms.
- Carbon is tetravalent, that is, it may form four single bonds with other atoms.
- Alkanes may have straight or branched carbon skeletons.

Objectives After completing this miniexperiment, a student should be able to*:

- Make ball-and-stick models of simple hydrocarbons.
- Have a greater understanding of the diversity of organic compounds.

Estimated Time One-half to one period

Student Grouping Students may work individually, in pairs, or in larger groups, depending upon the availability of model-making materials.

Materials** You will need the following materials for a class of thirty students*:

15 ball-and-stick *or* other model-making kits *or*
  90 25-mm (1") diameter Styrofoam balls
  225 20-mm (¾") Styrofoam balls
  5 boxes of toothpicks (*or* pipe cleaners)

Advance Preparation None

Prelab Discussion None is needed other than a reminder about the rules of carbon bonding (see section O-3).

Laboratory Tips Construct only single bonds in this activity. Your students will need experience in making molecular models and discussing their relevance to organic chemistry. Similar activities are suggested in several of the IAC modules. You should decide whether you wish to work with Styrofoam balls and toothpicks (or pipe cleaners) or molecular model kits which will show actual bonding angles of the molecular structure.

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*This statement appears only with this first miniexperiment, but it applies each time this section appears in an experiment or a miniexperiment unless otherwise noted.

**The *Materials* list for each experiment or miniexperiment in this module is planned for a class of thirty students working in pairs unless otherwise noted. You may have to adjust this to fit the size of your class.

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If your students work with molecular models, there are many types that can be purchased from science supply houses (addresses can be found in the teacher's guide for *Reactions and Reason*).

Lab-Aids, Inc., 130 Wilbur Place, Bohemia, NY 11716, produces several inexpensive student molecular model-building kits containing enough materials for up to 50 students. The atoms in each kit consist of plastic nuclei with pegs set at correct bonding angles to construct accurate three-dimensional models. The kits contain procedures, worksheets, and a teacher's guide prepared by the company. Some of the kits focus on hydrocarbons, esterification, functional groups, isomers, carbohydrates, fats, and carbon and diamond crystals. Write to the company for a price list and a description (also useful in experiments *O-9* and *O-51*).

If students are using Styrofoam balls and toothpicks (or pipe cleaners) instead of pre-bored model kits, illustrate the three-dimensional quality using these materials. The illustrations on pages 3 and 13 offer a three-dimensional view of these ball-and-stick models.

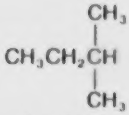
Postlab Discussion Allow students to compare models. If you are using model kits that present accurate bonding angles, point out the zig-zag pattern caused by the 109° bond angle between carbon atoms. If a good variety of branched chain compounds are produced you might consider combining sections *O-8* and *O-9* into an expanded lab with longer postlab discussion. The branching is what produces the great diversity.

You may find that some students have "bonded" three or four carbon atoms to a single carbon atom. Use this opportunity to focus attention on the concept of isomerism. Be sure that your students understand the concept of isomers since it will reoccur throughout the module.

Isomers, by definition, have the same molecular formula but different structures and properties. The more spherically shaped a molecule is, the lower the boiling point of the molecule. For the alkane homologous series discuss molar mass and its effect upon boiling point (b.p.). Have your students briefly examine the chart on page 18 to see if they note any pattern between molar mass and boiling point. Ask them to suggest an explanation as to why the boiling point increases as molecular mass increases. At this time you may wish to review the meaning of boiling in terms of molecular motion and air pressure since students will need this information in later sections of this module. Discuss the following isomers of pentane and their boiling points:

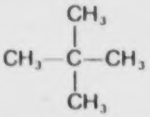
$CH_3CH_2CH_2CH_2CH_3$

b.p. 36°C



$CH_3CH_2\overset{CH_3}{\underset{CH_3}{CH}}$

b.p. 28°C



$CH_3-\overset{CH_3}{\underset{CH_3}{C}}-CH_3$

b.p. 9.5°C

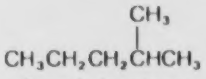
In the first printing of the student module, the boiling points of the pentane isomers (page 14) are incorrect. Point out to your students that the data should read:

n-pentane, b.p. 36°C
isopentane, b.p. 28°C
neopentane, b.p. 9.5°C

Have your students construct these pentane isomers using the ball-and-stick models. You may wish to extend this discussion by having them draw and/or build models for the isomers of C_6H_{14}. They should have five combinations as listed below:

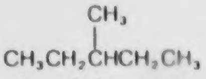
$CH_3CH_2CH_2CH_2CH_2CH_3$

n-hexane



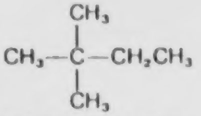
$CH_3CH_2CH_2\overset{CH_3}{CH}CH_3$

2-methylpentane



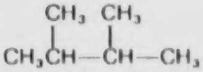
$CH_3CH_2\overset{CH_3}{CH}CH_2CH_3$

3-methylpentane



$CH_3-\overset{CH_3}{\underset{CH_3}{C}}-CH_2CH_3$

2,2-dimethylbutane



$CH_3\overset{CH_3}{CH}-\overset{CH_3}{CH}-CH_3$

2,3-dimethylbutane

The question may arise as to the naming of these isomers. You may wish to use student drawings and/or models to discuss nomenclature of hydrocarbons in preparation for mini-experiment *O-9*. Acquaint your students with *Appendix II: Nomenclature* (pages 124–126). For practice have them rename one isomer of *n*-butane and two isomers of *n*-pentane.

Ask an interested student to determine the differences in properties of the C_6H_{14} isomers. Another student might prepare a chart of the various properties of the isomers of hexane, pentane, and butane. Discuss any pattern in physical properties that is associated with molecular shape. For additional practice, refer your students to the table on page 18, section *O-12* to practice drawing the isomers for some other compounds in the alkane series.

MINIEXPERIMENT
O-9 BRANCHED-CHAIN MOLECULAR MODELS

Concept

- Branched-chain structures greatly increase the number of possible isomers for a given carbon atom.

Objective

- Make ball-and-stick models of branched hydrocarbons.

Estimated Time One-half to one period

Student Grouping Students may work individually, in pairs, or in larger groups, depending upon availability of model-making materials.

Materials

15 ball-and-stick model-making kits as described in section *O-8*.

Advance Preparation None

Prelab Discussion None is needed other than a reminder about the rules of carbon bonding.

Laboratory Tips Use only single bonds for this activity.

Postlab Discussion You may combine this with the postlab discussion of section *O-8* or if you do not wish to do so, then allow time for the students to compare and discuss models. Discuss the number of isomers that were made from four, five, and six carbons. Compare the number of branched and straight-chain compounds that are possible with each number. Have your students estimate the number that would be possible with eight carbon atoms. Draw and/or build them as a class project. You can have your students construct models and practice drawing the isomers of some of the larger structures in the alkane series. Refer students to the table on page 18, section *O-12*, asking them to name the compounds using the discussion of nomenclature in *Appendix II*, page 124 of the student module.

MINIEXPERIMENT
O-10 COMPARING PROPERTIES

This activity is designed to help students become aware of the differences in the combustibility of organic vs. inorganic compounds.

Concept

- Organic compounds can be distinguished from inorganic compounds by differences in combustibility.

Objective

- Classify a compound as organic or inorganic by determining its combustibility.

Estimated Time One period

Student Grouping Pairs

Materials

15 ring stands and rings
30 tin can lids, 10-cm diameter
15 Bunsen burners
15 wire gauze, plain
1 ball-peen hammer
5 g sucrose (sugar)
5 g sodium chloride
5 g *para*-dichlorobenzene
5 g calcium carbonate
5 cm^3 paraffin oil (mineral oil)
5 g naphthalene
5 g paraffin

You may substitute other materials such as the following:

$CuSO_4 \cdot 5H_2O$
bacon
polyethylene film
graphite
wood
paint from a pencil

Advance Preparation Have students bring can lids from home (large size). Making dents in the lid with a ball-peen hammer will help prevent mixing of samples. If you don't want to use can lids then use evaporating dishes which will allow for only one sample at a time. Clean dishes well after each sample use. While it is still warm, move the paraffin to a paper towel.

Laboratory Safety Review with your students the standard laboratory safety rules they should be following. Note the safety section in *Appendix I* at the end of the module.

Prelab Discussion None except a brief safety review.

Laboratory Tips Use only small samples of less than match-head size. Don't allow samples above this size. The smaller, the better. Limit investigations to four samples at a time to prevent contamination of one substance with another. **Caution:** *Remind your students to keep their heads and hair well back during the heating of samples.* The burner flame should come from the top and be directed onto each sample.

Range of Results Have the students tabulate their data on the chalkboard.

Burns	*Decomposes*	*No Change*
Naphthalene	$CuSO_4 \cdot 5H_2O$	NaCl
Paraffin		$CaCO_3$
para-Dichlorobenzene		
Sugar		

Postlab Discussion Center the discussion on collected student data. Compare inorganic and organic compounds. Evaluate your students' comprehension with questions similar to these:

1. If you were given a list of formulas for chemicals, some of which were organic and some inorganic, how could you recognize the organic compounds on the list?

   The ones containing C would be organic. However, be careful of carbonate (CO_3) salts of inorganic compounds.

2. Do you think *all* organic compounds (carbon-containing) will burn? Can you think of an example of one that doesn't burn?

   CCl_4 or other chlorinated hydrocarbons or even CO_2

3. Do you think *all* inorganic compounds do not burn?

   No.

   Can you think of any that burn?

   sodium or other active group IA metals

O-11 FUELS: HOW WELL DO THEY BURN?

Discuss the various hydrocarbons in different gasolines and relate them to the occurrence of engine knock in automobile motors. Point out that branched-chain structures reduce knocking, as do other ingredients.

Demonstration *Internal Combustion Engine:* If a demonstration model of an internal combustion engine is available from your physics teacher, demonstrate the operation of this type of engine and how engine knock can occur. You may wish to refer students to section *P-29* of *Communities of Molecules: A Physical Chemistry Module* for additional information on the internal combustion engine, burning of fuels, and engine knock.

Relate the photos on page 16 of the student module to your discussion of gasoline octane ratings and additives that raise the octane ratings of gasolines. Point out that octane rating is a comparison of how well a particular fuel burns with relation to isooctane. (The name isooctane is actually a misnomer—the real name is 2,2,4-trimethylpentane.) Some of your students may be interested in finding out how octane ratings are derived; a variety of sources are available that contain this information.

In discussing the various additives in gasolines, the following demonstration can be used to show the "dirty" burning of aromatic additives, such as toluene, in unleaded gasoline.

Demonstration Place a small amount of toluene on a watch glass, and ignite the fluid with a match. Note the color of the flame (turning off the light will produce a more dramatic effect). Compare this color to that of burning hexane in another watch glass. Note that hexane and alcohols (e.g., methanol and ethanol) burn cleanly while toluene gives off a sooty flame.

The color is evidence of the black soot being produced due to the "dirty" burning of the toluene.

Discuss the function and the hazards of tetraethyl lead (TEL) as a gasoline additive. The evidence of lead being discharged in automobile exhaust can be shown by setting up a lead detection lab exercise similar to *I-40* in *Diversity and Periodicity: An Inorganic Chemistry Module.* You may wish to initiate a discussion on lead poisoning and its effects on living organisms.

Catalytic converters are becoming more common on today's cars as part of an attempt to reduce air pollution caused by automobiles. Discuss the meaning of the term "catalytic converter." Some students may be interested to find out what types of material are used in catalytic converters, how these converters function, how durable they are, and why leaded fuels can render these devices useless.

Current research in catalytic converters utilizes a variety of chemicals to convert NO to nitrogen gas (N_2) and oxygen (O_2) gas, unburned hydrocarbons to water and carbon dioxide, and carbon monoxide to carbon dioxide. Metal oxides, such as copper and chromium oxide, and metals, such as platinum and palladium, are being employed to do these jobs.

Some students may wish to do research on emissions testing by writing to automobile manufacturers or visiting an auto emission center. Ask them to find out what automobile inspection stations measure when they sample engine exhaust and how measuring devices work.

Sometimes pollutants resulting from the burning of fossil fuels provide the raw material for more harmful chemical pollution. For example, NO_2 reacts with other substances to form PAN (peracyl nitrate). (Also refer to section *O-6* and review the environmental problem caused when SO_2 pollution produces sulfuric acid.)

Examine the equations on page 17 and ask your students how a dirty air filter may affect the production of carbon monoxide and, subsequently, pollute the surrounding environment.

O-12 SEPARATING HYDROCARBONS

This section provides information about the fractional distillation process—the first step in refining petroleum. This process may yield as many as 100 separate constituents. Relate the hydrocarbons present in gasoline to those on the table on page 18, having students provide an explanation of why gasoline hydrocarbons are drawn off near the top of the refining tower as shown on page 19. They should keep in mind the molecular mass of the compounds in question as well as their boiling points.

You may wish to have your students discuss the increasing usage of diesel engines in the United States. Refer again to section *O-11* and compare diesel fuel to gasoline. Interested students may wish to check on the differences between diesel and gasoline engines, determine the specific uses of the two fuels and the comparative efficiencies of each fuel under various driving conditions, and resulting pollution problems.

You may wish to discuss the fact that some of the higher boiling petroleum fractions are distilled under reduced pressure (partial vacuum). This is called a *vacuum distillation* and proves most valuable in cases where materials to be distilled are sensitive to high temperatures. (Review with your students the definition of boiling point or refer to *Communities of Molecules: A Physical Chemistry Module* for further discussion of this topic.)

Miniexperiment *Petroleum Derivatives:* After a discussion of the fractional distillation process ask students to make a list of products that they think come from petroleum—*petroleum derivatives.* You may wish to introduce this by referring to the photographs on page 20 of the student module. A chart of petroleum derivatives appears on the following page of this guide. This should give students an idea of the variety of products in use today that depend on petroleum for their manufacture. Duplicate copies of the chart for your students to examine and discuss; if this is not possible, post a copy of the chart for students to examine. (Chart is reprinted courtesy of Union Carbide Corporation. Many other oil and chemical producers also provide this type of information.) Students may find it interesting to suggest additional petroleum products to add to the list.

EXPERIMENT
O-13 FRACTIONAL DISTILLATION

This experiment will allow students to become familiar with a basic technique used to separate liquids in a mixture.

Concepts

- Fractional distillation is a useful technique to separate different liquids in a mixture.
- Materials can be separated in a mixture because of the differences in boiling points.

Objectives

- Apply the concept of fractional distillation in separating a mixture of liquids.
- Perform the fractional distillation process to separate a two- or three-component mixture.

Estimated Time One period

Student Grouping Pairs

Materials

15 125-cm^3 Erlenmeyer flasks
15 50-cm^3 graduated cylinders
15 2-hole stoppers to fit 125-cm^3 flasks
15 thermometers, −10°C to 110°C
30 18 × 150-mm test-tubes
30 400-cm^3 beakers
15 pieces glass tubing (6-mm diameter)
15 ring stands and rings
15 wire gauze, asbestos centers
15 Bunsen burners
1 clock for timing
300 cm^3 2-propanol
boiling chips
ice

Laboratory Safety Review with your students the safety precautions needed in performing this experiment—keeping hair away from the flame, not heating the flasks to dryness, and keeping flames away from the fumes of the distillate.

Advance Preparation Prepare the mixture that the students are to distill. A good mixture is 60 percent 2-propanol/40 percent H_2O, by volume. You can buy rubbing alcohol and dilute with water to reduce the alcohol from 70 percent to the needed 60 percent. Set up a model of the equipment for your prelab discussion. In selecting alternate mixtures for your students to distill, remember that some combinations form constant boiling (azeotrope) mixtures which cannot be separated by fractional distillation. Check azeotropes in the *Handbook of Chemistry and Physics* to determine if a different mixture you wish to use will form an azeotrope.

Prelab Discussion Discuss the physical setup of the distillation apparatus by comparing the demonstration setup you have provided with the apparatus suggested in the student module. Discuss reasons for any differences.

Laboratory Tips Caution: *Make sure stoppers are tight.* The thermometer tip should be just below the opening to the condenser tube as stated in the instructions of the student module. Caution students that alcohols *can ignite* if they boil out of the heating vessel—*slow* heating will prevent spattering or bumping. In addition, add several boiling chips to the flask. These chips provide a surface on which gas bubbles can form and escape from the boiling mixture. Additional hot water and ice will be necessary to replenish beakers as the experiment progresses and should be kept nearby.

Before beginning the experiment, students should carefully measure the amount of liquid given to them, recording this measurement in their notebooks.

Range of Results If you are using the suggested mixture, the following are the components and their boiling points.

2-propanol	81°C to 83°C
water	100°C

Besides gas for your car and heat for your home, can you name a few other things oil is used for?

Credit cards
American flags
Eyelashes
Aspirin
No-wax floors
Permanent-press clothes
Oxygen masks
Golf balls
Ink
Lighter fluid
Heart valves
Hair spray
Attache cases
Crayons
Steering wheels
Wet suits
Disposable diapers
Food wraps
Laxatives
Parachutes
Stretch pants
Trash cans
Telephones
Rubber duckies
Brassieres
Enamel
Seed tape
Wall coverings
Transparent tape
Card tables
Acrylic paints
Antiseptics
Golf cart bodies
Vacuum bottles
Vinyl siding
Slips
Shoe trees
Safety flares
Warm-up suits
Bearing grease
Overcoats
Ping-pong paddles
Rafts
Bubble bath
Purses
Sockets
Bookends
Weed killers
Flippers
Planters
Football pads
Tiles
Deodorant
Puzzles
Air conditioners
Panty hose
Backpacks
Tubs
Dish drainers
Rubbing alcohol
Shag rugs
Crabgrass killer
Epoxy paint
Lunch boxes
Puppets
Oil filters
Jerseys
Pajamas
Upholstery
Uniforms
Phonographs
Hearing aids
Welcome mats
Car sound insulation
Racks
Pacifiers
Dresses
Cassettes
Garment bags
Track shoes
Dominoes
Fences
Pond liners
Luggage
Kitchen counter tops
Protractors
Antifreeze
Earphones
Flashlights
Windbreakers
Whistles
Motorcycle helmets
Pillows
Clothesline
Dune buggy bodies
Carpet sweepers
Antibiotics
Checkers
Chess boards
Shower doors
Soap dishes
Yardsticks
Shorts
Syringes
Slip covers
Sugar bowls
Shoes
Paddles
Decoys
Volley balls
Tobacco pouches
Sleeping bags
Refrigerator linings
Pencils
Electrician's tape
Model cars
Midi-skirts
Kites
Folding doors
Mini-skirts
Floor wax
Garden hoses
Mascara
Paneling
Lawn sprinklers
Sweaters
Sneakers
Playing cards
Bread boxes
Earrings
Dolls
Bubble gum
Sandwich bags
Microfilm
Coasters
Raincoats
Sports car bodies
Stoppers
Straps
Smocks
Tennis balls
Tires
Tablecloths
Measuring cups
Rulers
Ring binders
Reclining chairs
Boat covers
Tote bags
Dishwashing liquids
Unbreakable dishes
Toothbrushes
Extension cords
First-aid kits
Notebooks
Combs
Watchbands
Darts
Flight bags
Toothpaste
Flea collars
Drip-dry dresses
Tents
Stadium cushions
Plastic varnish
Finger paints
Foul weather gear
Foot pads
Refrigerants
Rugs
Nightgowns
Sandals
Hair curlers
Lamps
Lipstick
Laminates
Ice cube trays
Typewriter cases
Visors
Swimming pool liners
Laundry softeners
Electric blankets
Ear plugs
Tennis rackets
Shirts
Drinking cups
Canisters
House paint
Lamp shades
Computer tape
Cough syrup
Rollerskate wheels
Movie film
Hair dryers
Guitar strings
Ammonia
Styrofoam coolers
Maxi-skirts
Gaskets
Brake fluid
Jugs
Monkey bars
Bathrobes
Eyeglasses
Vinyl tops
Digital clocks
Draperies
Ice chests
Life jackets
Audio tape
TV cabinets
Model planes
Car battery cases
Measuring tape
Insect repellent
Hockey pucks
Ice buckets
Fishing nets
Fertilizers
Hiking boots
Hair coloring
Knitting yarn
Toilet seats
Towel bars
Denture adhesive
Frisbees
Hair rollers
Light fixtures
Loudspeakers
Movie film
Panties
Electronic calculators
Fishing boots
Candles
Diving masks
Hairbrushes
Body suits
Water pipes
Pails
Car enamel
Guitar picks
Vinyl shingles
Switch plates
Shower curtains
Sponges
Detergents
Beach balls
Ties
Sunglasses
Bird houses
Bathinettes
Records
Typewriter ribbons
Footballs
Disposable lighters
Doorknobs
Sewing machine cases
Fishing reels
Mattresses
Lifeboats
Girdles
Diving boards
Luggage carriers
Blouses
Glue
Plastic drains
Kitchen gloves
Jackets
Bathroom scales
Fishing rods
Linoleum
Shelves
Plastic wood
Stuffed animals
Car mats
Soft contact lenses
Dog leashes
Dice
Trash bags
Thermal blankets
Drinking straws
Afghans
Pole vaulter poles
Foam insulation
Hand lotion
Shampoo
Shaving cream
Aquariums
Sails
Soft bumpers
Safety glass
Erasers
Radio cases
Awnings
Knitting needles
Fan blades
Wigs
Window shutters
Salad bowls
Epoxy glue
Punching bags
Model ships
Shavers
Plywood adhesive
Parkas
Football suits
Cameras
Shoelaces
Swizzle sticks
Piano keys
Bikinis
Bracelets
Football helmets
Anesthetics
Plungers
Artificial turf
Patio furniture
Ashtrays
Artificial limbs
Rain hats
Bandages
Dentures
Belts
Tongs
Tumblers
Car seats
Popcorn poppers
Poker chips
Mops
Bumper guards
Convertible tops
Clothes hangers
Cushions
Scarves
Chess figures
Tennis courts
Beach umbrellas
Ballpoint pens
Ant poison
Boats
Eye shadow
"Tiffany" lamps
Typewriter keys
Wire insulation
Desk organizers
Fake furs
T-shirts
Electric scissors
Golf bags
Skin conditioners
Photographs
Outdoor carpeting
Tool boxes
Salt shakers
Screen door screens
Sculptures
Caulking
Outboard motor housings
Tape recorders
Distributor housings
Window shades
Dog food dishes
Curtains
Dog toys
Lids
Pan handles
Slippers
Tennis shirts
Tent pegs
Tennis shorts
Vitamin capsules
Dashboards
Ribbons
Putty
Percolators
Swings
Skis
Tool racks
Folding chairs
Charcoal lighter
Gas siphons
Robes
Picture frames
Air mattresses
Petticoats
Seat covers
Slacks
Hampers
Lighting panels
Yarn
Jars
Stools
Wastebaskets
Wall plugs
Insecticides
Baby bottles
Fishing lures
Hoses
Perfumes
Shoe polish
Shower heads
Flavors
Petroleum jelly
Photo albums
Tranquilizers
Canteens
Snorkels
Faucet washers
Corrosion inhibitors
Signs
Room dividers
Name tags
Flower pots
Pipes
Projection screens
Slide trays
Chop sticks
Ski boots
Food preservatives
Antihistamines
Slides
Squeeze bottles
Soil conditioners
Cortisone
Ski poles
Vinegar
Mouthwash
Oven bags
Sedatives
Dyes
Display cases
Streamers
Paint brushes
Air filters
Balloons
LP records
Vaporizers
Solvents
Razors
Dry-cleaning fluid
Waxed paper
Cigarette filters
Gloves
Roofing
Cold cream
Carbon paper
Wallets
Bedspreads
Patio screens
Darkroom trays
Synthetic rubber
Badminton birdies
Glycerin
Hang gliders
Water softeners
Rubber cement
Iron-on patches
Grease pencils
Ballet tights
Nylon rope
Price tags
Masking tape
Water skis
Paint sprayers
Fan belts
Mittens
Blenders
Humidifiers
Camera bags
Umbrellas
Ponchos
Paint rollers
Shopping bags
Antenna cable
Bird feeders
Exercise mats

We could go on and on. All of these things—plus many more—are made with petrochemicals for which oil is a basic raw material. The point is that oil is much more important in our lives than we often realize.

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Postlab Discussion Write collected student data on the chalkboard, and discuss the observed results and variations. Students should measure the volume of the components of their distillations. These will be used to compute the percent composition in the total mixture. After they have calculated the amounts of 2-propanol and water which they collected, the following questions may arise. Does the total of the amounts collected (2-propanol and water) equal the total original volume? Why or why not? Ask students why there may be discrepancies in proportions of 2-propanol and water from the original mixture. For example, 2-propanol evaporates more readily than water, which may account for some loss during the collection stage in which the collecting tube is open. Heating that is too rapid may also explain some loss.

Formula for Percent Composition:

$$\frac{\text{amount of one component}}{\text{total amount of distilling mixture (total original volume)}} \times 100 = \text{percent of one component in total mixture}$$

Focus further discussion on the usefulness of fractional distillation for separating petroleum into its by-products.

EVALUATION ITEMS

These are suggestions for evaluation items which you may wish to use with your students at various times during the preceding section. The correct answer to each question is indicated by shading.

1. Which of the following compounds is *not* a hydrocarbon?

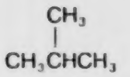
   A. CH_4 C. C_5H_{12}
   B. $C_6H_{12}O_6$ D. C_6H_6

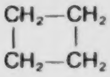
2. Briefly describe how a fuel you burn today, such as coal, natural gas, and oil, might be considered as burning "dead dinosaurs."

   (See student module discussion, section *O*-5.)

3. Which of the following structures is *not* an alkane?

   A. $CH_3CH_2CH_3$ C. $CH_2{=}CHCH_3$

   B. 
   $CH_3CH(CH_3)CH_3$

   D. 
   $\begin{matrix} CH_2-CH_2 \\ | \quad\quad | \\ CH_2-CH_2 \end{matrix}$

4. Draw three structural isomers of the alkane, pentane (C_5H_{12}).

   (See student module *O-8*, page 14.)

5. An octane rating of 90 is equal to a mixture of

   A. 90 percent isooctane and 10 percent *n*-heptane.
   B. 90 percent *n*-heptane and 10 percent isooctane.
   C. 90 percent octane and 10 percent *n*-heptane.
   D. 90 percent octane and 10 percent *n*-hexane.

6. A compound in the following list most likely to burn is:

   A. potassium nitrate (KNO_3)
   B. silver chloride (AgCl)
   C. nonane (C_9H_{20})
   D. calcium carbonate ($CaCO_3$)

7. The combustion of hydrocarbons yields all of the following *except:*

   A. CO_2 C. H_2O
   B. CO D. CH_4

8. How are the processes of combustion and photosynthesis related?

   (See student module, sections *O-4* and *O-5*.)

9. On what property of a mixture does the technique of fractional distillation depend?

   differences in boiling points of the components

10. Name as many fossil fuels as you can. How is the name "fossil fuel" derived?

    (This is an open-ended question; refer to student module for a definition.)

11. Name three problems associated with the use of tetraethyl lead in gasolines in order to increase octane rating.

    lead pollution, fouling of automobile engines, and ruining catalytic converters

12. Rank these fuels in order of *increasing* boiling points. kerosene, paraffin, natural gas, diesel oil, gasoline. Then tell why this information is of interest to petroleum refiners.

    natural gas, gasoline, kerosene, diesel oil, paraffin

    Boiling points of specific fuels are important to petroleum refiners because they can determine a physical method by which each important petroleum fraction can be removed from the original crude oil.

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"Links in the Hydrocarbon Chain." *Science News*, January 29, 1977.

A report on research findings that the lengths of bonds in a long hydrocarbon molecule differ from the lengths of bonds in shorter hydrocarbons.

Maisel, A. Q. "The 'Clean-Auto' Law is the Wrong Answer." *Reader's Digest*, September 1972.

"Origins of Sulfur in Coal: Importance of the Ester Sulfate Content of Peat." *Science*, February 18, 1977, pp. 675–77.

Pierce, J. R. "The Fuel Consumption of Automobiles." *Scientific American*, 232(1), p. 34 (1975).

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Taking Things Apart and Putting Things Together. American Chemical Society. (For a copy, write to: 1155 16th Street, N.W., Washington, DC 20036, pp. 73–82) 1976.

Discussion of our energy resources and the effects on the environment due to their use.

The Story of Natural Gas Energy. American Gas Association. (For a free copy, write to: 1515 Wilson Blvd., Arlington, VA 22209) 1977.

Wildeman, T. R. "The Automobile and Air Pollution: A Chemical Review of the Problem." *Journal of Chemical Education*, 51(5), p. 290 (1974).

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SUGGESTED FILMS

Alkanes—The Saturated Hydrocarbons. Color, 30 minutes. Encyclopaedia Britannica Educational Corp., 425 N. Michigan Ave., Chicago, IL 60611.

Alkenes and Alkynes—The Unsaturated Hydrocarbons. Color, 30 minutes. Encyclopaedia Britannica Educational Corp., 425 N. Michigan Ave., Chicago, IL 60611.

Catalysis. Color, 17 minutes. A CHEM Study Film. Modern Learning Aids, Division of Ward's Natural Science Establishment, Rochester, NY.

Presentation of catalysis at work in animated form, and discussion of potential energy in catalyzed and uncatalyzed reactions.

Control of Air Pollution. Color, 5 minutes. U. S. National Audiovisual Center, General Services Administration, Washington, DC 20409. Attention: Order Section/RR.

Effects of Air Pollution. Color, 5 minutes. U. S. National Audiovisual Center, General Services Administration, Washington, DC 20409. Attention: Order Section/RR.

Energy for the Future. Color, 17 minutes. Encyclopaedia Britannica Educational Corp. 425 N. Michigan Ave., Chicago, IL 60611.

A look at energy alternatives to fossil fuels.

The Invisible Power of Coal. Color, 28 minutes. Modern Talking Picture Service, 2323 New Hyde Rd., New Hyde Park, NY 11040.

Portrays the past and the present of the coal industry and the importance of coal as fuel and as raw material for many other industries.

Natural Gas—Energy In the Home. Color, 13½ minutes. American Gas Association, Film Service Library, 1515 Wilson Blvd., Arlington, VA 22209.

Natural Gas—Flowing Energy. Color, 10 minutes. American Gas Association, Film Service Library, 1515 Wilson Blvd., Arlington, VA 22209.

Illustrates the application of science principles in the control of natural gas flow in a distribution system.

The Photosynthesis and Respiration Cycles. Color, 14 minutes. Churchill Films, 622 N. Robertson Blvd., Los Angeles, CA 90069.

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Refinery At Work. Color, 21 minutes. Modern Talking Picture Service, 2323 New Hyde Rd., New Hyde Park, NY 11040.
Discusses the chemical and mechanical processes for refining petroleum.

Refinery Process. Color, 20 minutes. Shell Film Library, 450 N. Meridian St., Indianapolis, IN 46204.
Introduces the chemistry of refining crude oil into petroleum products. Includes use of catalysts in the formation of high-octane gasoline.

Sources of Air Pollution. Color, 5 minutes. U.S. National Audiovisual Center, General Services Administration, Washington, DC 20409. Attention: Order Section/RR.

Symbol of Science. Color, 10 minutes. Association-Sterling Films, 866 Third Ave., New York, NY 10022.
Describes how petroleum is formed and the procedures used in oil exploration.

Reactions of Hydrocarbons

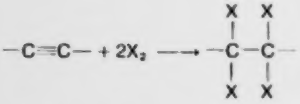
We continue the study of hydrocarbons by examining typical hydrocarbon-containing compounds to determine the properties that help chemists group them for study, analysis, and useful synthesis. Hydrocarbons vary in reactivity —from nonreactive to very reactive; by examining their structures students will become more familiar with the bonding that is responsible for this reactivity. From the introductory discussion, students will note that the reactivity in hydrocarbon compounds is dependent on the different types of bonding that these molecules can undergo.

As your students can see from the photograph on page 22 of the student module, one group of hydrocarbons is very reactive and is responsible for the production of commonly used explosives. We examine the constructive uses of explosives, focusing on the safe and economic usage of these chemical compounds in accomplishing jobs that once were time-consuming and hazardous for the workers involved. Modern use of explosives in demolition work is much safer, less expensive, and more efficient, and its impact is dramatic and fascinating. (Students might wish to research recent magazine articles on this subject.) Explosives are often presented in an unfavorable light by the "media." This is because, as is the case with many other chemical compounds, they are sometimes misused. We have presented material that will help students understand the compounds in question, in terms of chemistry. Depending on your students, you may wish to limit the material or extend discussions and stimulate additional interest by providing more information on this topic.

O-14 HOW STRONG THE BOND THAT BINDS

This section focuses on the bonding properties of carbon that are responsible for the reactivities of the different classes of hydrocarbons: alkanes, alkenes, alkynes, cyclic hydrocarbons, and fused aromatic rings.

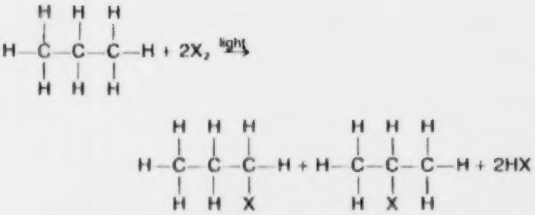
Review with your students the fact that double and triple bonds indicate the sharing of two and three pairs of electrons, respectively. Double and triple bonds (in alkenes and alkynes) are weaker than the single bonds of the alkanes, which render these compounds more chemically reactive. Because of this, double and triple bonds usually undergo *addition reactions,* particularly with hydrogen and the halogens. You may wish to review the halogens with your students before proceeding with the following example. Point out that the X can represent any halogen (Cl_2, Br_2, I_2).



$$-C\equiv C- + 2X_2 \longrightarrow -\overset{X}{\underset{X}{C}}-\overset{X}{\underset{X}{C}}-$$

As you discuss the different addition reactions that can occur, point out that these reactions yield one product, whereas single bond reactions that undergo substitution yield at least two products.

You can use the following equation to demonstrate the reactivity of single-bonded compounds. Again, any halogen can be substituted for the X in the equation.



$$H-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-H + 2X_2 \xrightarrow{\text{light}} H-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{X}{C}}-H + H-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{X}{C}}-\overset{H}{\underset{H}{C}}-H + 2HX$$

Since single-bonded compounds are the most stable, a catalyst is required in order for a reaction to occur (to break the bonds). You may wish to review the definition of the term catalyst with your students as you proceed with the discussion. In the above example it must be remembered that any of the hydrogen atoms could have been replaced by an *X*.

The concept of saturated and unsaturated molecules is also introduced in this discussion. As you discuss the definitions of these terms, relate this concept to the bonding potential of carbon. This will help students to determine which molecules are saturated and which are unsaturated. You may wish to provide further practice to help your students understand the important concepts of addition and substitution reactions in conjunction with saturated and unsaturated compounds.

More interested students may wish to check on other triple-bonded compounds and their importance. Others may wish to review the compound acetylene to find out more about its uses and why other methods are being substituted for its once better known use—welding and cutting of steel.

O-15 CHAINS AND RINGS

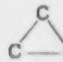
Note that *cyclo*alkanes (saturated carbon ring compounds) have the same general formula as alkenes, C_nH_{2n}. The physical and chemical properties of the larger ring hydrocarbons ($\geq C_5$) are very similar to those of their straight-chain analogs. If saturated with hydrogen at high temperatures, the smaller ring structures (C_3 and C_4) will break and the corresponding straight-chain hydrocarbon will result, as illustrated with cyclobutane and cyclopropane in the following reactions:

$$\text{cyclopentane} + H_2 \xrightarrow[\text{high temperature}]{\text{catalyst}} \text{no reaction}$$

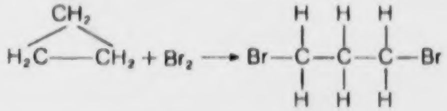
$$\text{cyclobutane} + H_2 \xrightarrow[200\,^{\circ}C]{\text{catalyst}} CH_3CH_2CH_2CH_3$$

$$\text{cyclopropane} + H_2 \xrightarrow[120\,^{\circ}C]{\text{catalyst}} CH_3CH_2CH_3$$

The reason for the great increase in reactivity of cyclobutane and cyclopropane can be attributed to the large amount of "strain" in these small rings. This can be seen readily by trying to construct these rings with ball-and-stick models; it can't be done. In the normal alkanes, the four atoms surrounding a carbon atom are as far apart from one another as they can be, that is, the bond angles are 109.5°. However, in cyclopropane

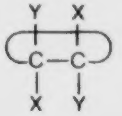


the bond angle must be only 60°. Hence, there is a great deal of strain in this ring. This strain can be relieved by reacting with a reagent to give ring-opened products:

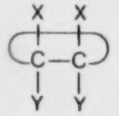


The larger rings, those with more than four carbon atoms, are somewhat flexible. This can be seen most easily with the use of models.

Groups substituted on a ring may be on the same side (*cis*-) or on the opposite side (*trans*-) of the ring with respect to each other (for further discussion see section *O-55* of the student module). These rings may be viewed as being planar, making it easier to appreciate the relationship that substituted groups have on the ring.



trans



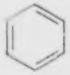
cis

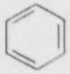
To further the discussion of hydrocarbons and rings used in anesthetics ask if any of your students have had experiences with general anesthetics. If so, you may wish to have them discuss their experiences and lead into a further discussion of how nearly all anesthetics (e.g., ether, chloroform, and cyclopropane) are volatile, nonpolar compounds. Apparently, anesthetics dissolve in the protective sheath (myelin sheath) surrounding the nerve cells. This sheath is composed of lipids (compounds in living organisms that are water insoluble but soluble in hydrocarbons, such as fats), and the introduction of foreign material in sufficient concentrations will interfere with the conductance of the nerve impulse thereby relieving or deadening pain. You may wish to have your students research the topic of anesthetics to determine which compounds are used.

O-16 THE BENZENE RING

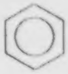
As was pointed out earlier in the module, a double bond reacts in the same manner whether it is in a ring or not. Even two double bonds in a ring follow the same pattern. However, in the case of benzene there is a special stability of three alternating double bonds. Because of this stability, the benzene ring does not usually undergo addition reactions.

The usual reaction is that of substitution, whereby a hydrogen atom is replaced by some other group. Again, the stability of the ring is evidenced by the fact that catalysts are needed to achieve the substitution. The stability is due to the resonance of the alternating double bonds. Two structures





can be drawn. In reality the actual molecule is viewed as not having three double and three single bonds, but rather six bonds of equal properties (length, energy, etc.). The bond is a hybrid of a double and a single bond. An often used structure



shows that the single and the double bonds are everywhere in the ring at once.

Organic chemists frequently show only the geometric ring when they draw structural formulas for ring compounds. The carbon atoms are not labeled, or identified; rather, each vertex represents a carbon atom within the structure.

Explain to your students that the prefix *para-* refers to the relationship of the substitutents on the benzene ring. The functional groups (substitutents) are on the 1 and 4 carbon atoms for *para*. If they are on the 1 and 3 positions, it is referred to as *meta*, and if they are next to each other (1 and 2 positions), it is called *ortho*. (See *Appendix II: Nomenclature* in the student module, pages 124–126.)

At this point, certain questions about aromatic substitution reactions may arise. The two most common areas deal with **(1)** ease of reaction—what governs how fast (at what rate) reagents will react with each other and **(2)** what determines the position of substitution in the ring. Why is only *p*-dichlorobenzene and not *o*- and *m*-dichlorobenzene produced from the chlorination of benzene?

Review the derivatives of benzene found on page 27 of the student module, noting that changes on the ring occur at the *ortho*, *meta*, and *para* positions, making each compound structurally and chemically different. You may wish to add additional structures to this list to demonstrate this point more clearly.

Actually, one does obtain these other isomeric dichlorobenzenes. Nearly as much *o*-dichlorobenzene is formed as *p*-dichlorobenzene, but only a small percentage of the *meta* isomer results. We would say that the first chlorine atom added to the benzene ring *directs* the new incoming chlorine atom to the *ortho* or the *para* position of the ring.

The bonding of benzene puzzled chemists for many years. Interested students may wish to find out more about this and the interesting story of how the chemist, Kekulé, was able to determine the bonding of the benzene molecule. The margin illustration of the commemorative stamp on page 26 of the student module provides some material for this topic.

The ease of reactivity in substitution reactions of the aromatic compounds varies tremendously. Phenol reacts with chlorine a billion times faster than nitrobenzene reacts with chlorine.* Phenol is so reactive that no catalyst is required. The ease of reaction of phenol with chlorine presents an environmental problem. Some chemical plants discharge phenol (a common industrial chemical) into streams that may be used as sources for municipal water supplies. If the phenol is not carefully removed during the water treatment, upon subsequent chlorination of the water (for disinfectant purposes), the phenol reacts to give chlorinated phenols. These chlorinated phenols are extremely foul tasting, even at very low concentrations (only several parts per million). Your students might be interested in visiting a water treatment center to study this problem further themselves.

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*This would mean that if it takes phenol only one minute to react with chlorine, it will take nitrobenzene nearly 2000 years to undergo this same reaction.

MINIEXPERIMENT
O-17 REACTIONS OF HYDROCARBONS

The purpose of this experiment is to compare the reactivities of toluene, cyclohexane, and cyclohexene with potassium permanganate.

Concept

- The double bond in organic structures is a "reaction site."

Objectives

- Identify saturated structures as compared to unsaturated structures.
- Predict reactivity of unsaturated compounds based upon structure.

Estimated Time 30 minutes to one-half period

Student Grouping Pairs

Materials

45 13 x 100-mm test tubes
15 test-tube racks
15 stoppers *or* corks for test tubes
15 10-cm^3 graduated cylinders
50 cm^3 toluene
50 cm^3 cyclohexane
50 cm^3 cyclohexene
150 cm^3 0.01 M $KMnO_4$

Advance Preparation

0.01 M $KMnO_4$: Dissolve 1.58 g $KMnO_4$ per 1000 cm^3 and acidify slightly with 0.1 M HCl.

Obtain stock solutions of toluene, cyclohexane, and cyclohexene. Try the experiment with your cyclohexane and toluene samples. Impure reagents give a green color. These samples may be cleared up by pretreatment with 0.1 M $KMnO_4$ and HCl until no further color change occurs.

Prelab Discussion Many schools and research laboratories now prohibit the use of benzene for health-related reasons. You may wish to discuss with your students why toluene is being used in place of benzene (safety hazards, risk of leukemia, etc.). (Toluene is metabolized to benzoic acid which is easily converted to sodium benzoate, a common preservative.)

Laboratory Safety Adequate ventilation should be provided when using liquid hydrocarbons. Students should not pour contents of test tubes into the laboratory sink. Use a common waste jar.

Laboratory Tips Demonstrate to your class the proper techniques of dispensing reagents; contamination of samples will give faulty results.

Postlab Discussion Allow students to conclude through interpretation of their results that the greatest reactivity occurred with cyclohexene, the double-bonded structure.

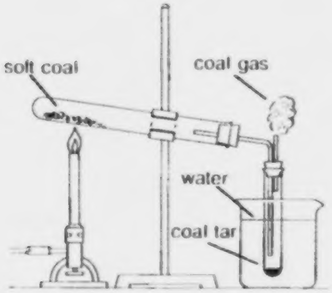
Answers to Questions page 28 The presence of a single double bond in cyclohexene provided a reaction site. Therefore cyclohex*ene* reacted first. Slight reaction of toluene could be due to an impurity or oxidation to benzoic acid. Evidence for a chemical change was the visual observation that the potassium permanganate decolorized from pink to clear or turned brown (MnO_2).

O-18 FUSED RINGS:
BIGGER BUT NOT BETTER

Ask your students to bring naphtha and mothballs to class. Have each student smell the naphtha and the mothballs. Ask how they would classify the compounds which these products contain. As the student module explains, mothballs are made of *para*-dichlorobenzene (page 28). Both *p*-dichlorobenzene and naphthalene are aromatic compounds. Naphthalene, in addition, is a fused-ring compound. These rings are represented by alternating single and double bonds in six-membered carbon rings. (See the illustration of benzopyrene on page 29 of the student module.)

As mentioned in the student text, coal tar is also composed of a large number of compounds many of which contain fused benzene rings. Suggest to your students that they bring in samples of coal tar products such as pitch and creosote. These products can be obtained from a hardware store or from a building-supplies outlet. The lesson can be extended by doing the simple laboratory experiment in which coal tar is produced.

Miniexperiment Place a few pieces of soft coal in a test tube. Connect this test tube to another test tube which is used for collecting gas and coal tar. The second test tube is placed in a beaker containing water. Heat the coal over a Bunsen burner. The destructive distillation produces coke, coal gas, and coal tar. The coke remains in the first test tube which is being heated while the coal tar settles at the bottom of the collecting bottle (test tube), and the coal gas escapes through the open glass tube. Bring a flaming match near the mouth of the glass tube from which the coal gas escapes. Observe the burning gas.



Benzopyrene found in coal tar is one of the compounds comprising cigarette smoke. Over the years much money and time has been devoted to the research of the effects cigarettes have on our society. The American Cancer Society (777 Third Avenue, New York, NY 10017), the National Foundation for Cancer Research (7315 Wisconsin Avenue, Suite 85 1W, Bethesda, MD 20014), the American Association for Cancer Research (Memorial Sloan-Kettering Cancer Center, 1275 York Avenue, New York, NY 10021), and the American Lung Association (for address, see teacher's guide section O-6) will be able to provide you with information on this topic as well as with kits used for determining the amount of tar in a cigarette and other demonstrations you may wish to perform. You might want to invite someone to come and speak on this controversial topic, and to bring you up-to-date on the latest research and what the future holds.

O-19 MOLECULES WITH A BANG

The "explosive" nature of TNT, nitroglycerine, and dynamite lies in the release of great amounts of heat (energy) and the production of stable nitrogen gas. The rapid heating and expansion of the gas produces the "explosion."

Point out to your students that although these compounds are quite dangerous they also have practical uses when handled correctly. The demolition of buildings and bridges, for instance, would be nearly impossible if it were not for the use of explosives.

A discussion of rocket propellants and the work of Alfred Nobel might be of interest here. Recent Nobel Prizes awarded in the field of organic chemistry (student module page 32) may be the basis for an interesting and informative exercise for students who would like to find out what research the chemists were involved in.

EVALUATION ITEMS

These are additional evaluation items that you may wish to use with your students at various times during the preceding section. The correct answer to each question is indicated by shading.

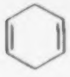
1. Double bonds usually undergo which of the following types of reactions?

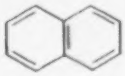
   A. substitution   C. photolysis
   B. addition   D. neutralization

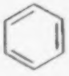
2. Which of the following compounds is most likely to undergo an addition reaction?

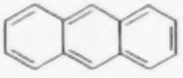
   A. $CH_2{=}CH{-}CH_3$ C. $CH_3CH_2CH_2CH_3$
   B. CH_4 D. CH_3CH_3

3. Which of the following is not an aromatic hydrocarbon?

A. 

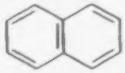
C. 

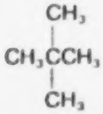
B. 

D. 

4. The compound most likely to decolorize a solution of potassium permanganate is:

A. CH_3CH_3

C. 

B. 

$CH_3C(CH_3)_2CH_3$

D. $CH_3CH{=}CHCH_2CH_3$

5. The following reaction

$$C_3H_8 + 2Cl_2 \xrightarrow{light} C_3H_6Cl_2 + 2HCl$$

is an example of
A. an addition reaction.
B. a substitution reaction.
C. an oxidation reaction.
D. a neutralization reaction.

6. An element that is usually found in explosives is

A. nitrogen.
B. sulfur.
C. aluminum.
D. carbon.

7. Have a class debate on the merits and dangers of the continued use of products, such as explosives, benzene, chlorinated hydrocarbons, that are both beneficial as well as harmful to our society (environment). (This could also be used as a short essay format.)

SUGGESTED READINGS

Beecher, H. K. "Anesthesia." *Scientific American*, June 1959, p. 90.

"Benzene—The Story of Its Formula." *Chemistry*, February 1966.

Hallstead, William F. "Big Bang on the Boardwalk." *Popular Mechanics*, May 1973, p. 122.
An account of the demolition of the Traymore Hotel in Atlantic City by Jack Loizeaux, one of the foremost explosives experts.

——. "Blow Up Buildings Safely—It's Dynamite." *Science World*, October 4, 1973, pp. 18–20.

"Monkey Models of the Benzene Ring." *Journal of Chemical Education*, 444:35 (1958).

Satchell, Michael. "The Loizeaux Family: They Get Paid for Precision Bombing." *Parade*, June 18, 1978, pp. 4–5.

Schaar, Bernard. "Chance Favors the Prepared Mind." *Chemistry* Reprint No. 80.
Fascinating stories of 13 accidental scientific discoveries. Topics covered include aniline dyes, quinine, dynamite, and artificial sweetners.

Sears, J. A. "Unintentional Discoveries." *Chemistry*, January 1971, p. 16.
Includes an account of the discovery of dynamite.

Vanderbilt, B. M. "Kekulé's Whirling Snake: Fact or Fiction?" *Journal of Chemical Education*, 52(11), p. 709 (1975).

SUGGESTED FILM

Explosives—Tools For Progress. Color, 22½ minutes. Association-Sterling Films, 866 Third Ave., New York, NY 10022.
Depicts the safe use of commercial explosives as essential factors in the development of modern society.

Alcohols: Oxidized Hydrocarbons

This section on alcohols presents the first level of oxidation beyond the hydrocarbons. Again, you will be stressing *functional groups* and their importance to organic chemistry. The fact that functional groups *determine the properties* of organic compounds is a major concept that all your students should fully understand. As you proceed through this section, you may wish to refer to *Appendix II: Nomenclature* (page 125) in discussing the naming of alcohols.

O-20 OXIDATION AND REDUCTION

To introduce alcohols, briefly review oxidation and reduction as the students have previously studied these terms. The equations on page 34 of the student module represent an oxidation reaction and a reduction reaction.

Frequently, organic chemists define oxidation as the combination of carbon with oxygen, eventually forming CO or CO_2 when oxidation is complete. Reduction is defined as the combination of carbon with hydrogen. Write the word equation, methane plus oxygen yields methyl alcohol, on the chalkboard. Explain to your class that methane (CH_4) yields methyl alcohol (CH_3OH) when it oxidizes (in the presence of oxygen).

Form and Function does not discuss valences or oxidation states. If your students are interested in pursuing these topics in depth you may wish to suggest additional readings.

The simplest forms of oxidized hydrocarbons are the alcohols, in which a single oxygen atom bonds to a carbon atom in place of a hydrogen atom. As an introduction to the next section, *O-21,* discuss with your class how alcohols are derivatives of hydrocarbons and how the addition of oxygen affects the bonding properties, boiling points, and miscibility of these compounds.

The addition of oxygen as a definition of oxidation is in keeping with the more rigorous definition of loss of electrons. Oxygen is more electronegative than carbon, and, hence, the electron pair (or pairs) shared between carbon and oxygen are attracted more to the oxygen atom and are lost to the carbon atom.

The addition of hydrogen may be viewed as reduction in that the pair of electrons shared between the hydrogen and the carbon atoms are attracted more to the carbon atom (because of its higher electronegativity), and, therefore, the carbon atom has gained electrons. The gain of electrons is the more rigorous definition of reduction.

O-21 METHYL AND ETHYL: THEIR PROPERTIES

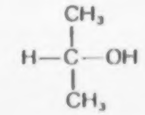
One of the most surprising differences in physical properties between alcohols and their hydrocarbon analogs is the difference in boiling points. Ethane (30 grams per mole) boils at −89°C, while methyl alcohol (32 grams per mole) boils at +65°C, a difference of 150°C. What are the boiling points of ethyl alcohol and propane? How do these compare with those already mentioned?

The other major difference in physical property is the ability of the low molecular weight alcohols to dissolve many materials that are insoluble in the liquid hydrocarbons. This ability —to be a good solvent—is caused by the polar nature of alcohols and the ability to form hydrogen bonds, as water molecules do. For further discussion of polar bonds see *Reactions and Reason: An Introductory Chemistry Module.*

The properties of alcohols change as more carbon atoms are added to the chain. Propyl alcohols, normal (*n*) and iso (*i*), are miscible with water, but the butyl alcohols are only partially soluble in water. If the molecular weight of the alcohol becomes too high, it behaves like a hydrocarbon and is, therefore, water insoluble.

$$CH_3{-}CH_2{-}CH_2{-}OH$$

n-propyl alcohol



$$\mathrm{H{-}\overset{\overset{CH_3}{|}}{\underset{\underset{CH_3}{|}}{C}}{-}OH}$$

iso-propyl alcohol

$$CH_3{-}CH_2{-}CH_2{-}CH_2{-}OH$$

n-butyl alcohol

Point out that ethyl alcohol (ethanol) is so common that almost everyone, including chemists, refer to it simply as "alcohol." Similarly, almost everyone refers to diethyl ether as "ether." Its boiling point is 34°C, which is lower than normal body temperature and is a commonly used anesthetic. It is popular because of its low toxicity and high effectiveness. However, it is extremely flammable. The odor of diethyl ether is responsible for much of the familiar "hospital smell."

Because diethyl ether boils so close to room temperature, it is very volatile and evaporates easily. The behavior of this liquid, first discovered in 1544, must have been somewhat of a mystery to early chemists. It just disappeared before their eyes. This fleeting liquid was named "spiritus aethereus" after the Greek word "aether," which is what the ancient Greeks called the region above the Earth's upper atmosphere. The name was eventually shortened to ether. Later when the molecular structure of diethyl ether became known, the name *ether* was used for the class of compounds to which diethyl ether belonged. In fact, ether was extended to the related hydrocarbon C_2H_6, and this hydrocarbon became known as ethane.

Plan on using molecular models to illustrate the structural similarities between water, methyl alcohol, and ethyl alcohol. Refer to the structural formulas on pages 34 and 35 of the student module. Use the structural difference between ethanol and diethyl ether as an introduction to the next section.

Miniexperiment As a further exercise have your students construct a table of common alcohols, draw their structures, state boiling points, and determine how these alcohols are used (industrially or in the home).

O-22 ANOTHER TYPE OF BONDING

Examine the hydrogen bond arrangement on page 36 of the student module. Stress that energy is needed to overcome the forces that hold this arrangement intact, hence, the compound exhibits a higher boiling point. If you wish you may discuss the differences in electronegativity between O and H molecules combined with the geometry of the H_2O molecule which leads to the formation of hydrogen bonds. These two factors are also present in the hydroxyl group of alcohols. Discuss with your class the difference between the hydroxide ion and the hydroxyl group. *Diversity and Periodicity: An Inorganic Chemistry Module* and *Reactions and Reason: An Introductory Chemistry Module* are also excellent reference sources for discussion of hydrogen bonding.

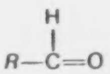
O-23 FUNCTIONAL GROUPS: FOCUS OF THE MATTER

This section introduces, in a formal manner, the concept of the *functional group*. The hydroxyl group just studied is a prime example. The functional group is the part of the molecule that gives it its properties and dictates what type of reaction the molecule will undergo and, in many cases, the manner or path that the reaction will take.

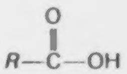
Spend time discussing the table of functional groups on page 38 of the student module. Encourage your students to memorize these groups as they will be used repeatedly throughout the text. Remind them to make a mental note of the placement of this chart as it may be needed for later reference.

Point out to students that chemists write molecular formulas for compounds containing functional groups as

$R{-}OH$



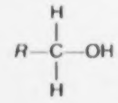
$$\begin{array}{ccc} & H & \\ & | & \\ R- & C & =O \end{array}$$



$$\begin{array}{ccc} & O & \\ & \| & \\ R- & C & -OH \end{array}$$

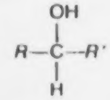
where *R* represents the hydrocarbon portion of the molecule. By knowing the basic reactions of the more common functional groups, the student will be able to easily master the reactions of organic molecules. Compounds with the same functional group have similar chemical properties. For example, all organic compounds with the carboxylic acid group behave as acids and donate protons. They will turn litmus paper red and will react with bases to give salts.

You can extend your lesson on functional groups by explaining that alcohols can be classified as being either *primary, secondary,* or *tertiary*. The location of the hydroxyl group determines the classification. (See *Appendix II,* page 125.) An alcohol is classified as a *primary* alcohol if the hydroxyl group is attached to a primary alkyl group. (A primary alkyl group consists of a carbon atom attached directly to only one other carbon atom.)



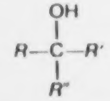
$$\begin{array}{ccc} & H & \\ & | & \\ R- & C & -OH \\ & | & \\ & H & \end{array}$$

Ethyl alcohol is an example of a primary alcohol. An alcohol is known as a *secondary* alcohol when the hydroxyl group is attached to a carbon atom bonded to two other carbon atoms.



$$\begin{array}{ccc} & OH & \\ & | & \\ R- & C & -R' \\ & | & \\ & H & \end{array}$$

An example of a secondary alcohol is isopropyl alcohol. The carbon atom bonded to the hydroxyl group is also bonded to three other carbon atoms in a *tertiary* alcohol.



$$\begin{array}{ccc} & OH & \\ & | & \\ R- & C & -R' \\ & | & \\ & R'' & \end{array}$$

An example of a common tertiary alcohol is t-butyl alcohol.

Reinforce your lesson on primary, secondary, and tertiary alcohols with the use of molecular models. Construct a model to represent each alcohol group, showing students that the position of the hydroxyl group is important in determining the properties of the alcohol. The understanding of this concept will be helpful in the discussion of amines, section *O-44*.

O-24 FERMENTED AND DISTILLED ALCOHOLS

Of the many alcohols existing today, three may be singled out for discussion—ethyl alcohol (ethanol or grain alcohol), methyl alcohol (wood alcohol), and glycerol (glycerin).

Ethyl alcohol is manufactured by the fermentation of carbohydrates or synthesized from ethylene. It is the alcohol base of "alcoholic" beverages prepared by the fermentation of sugar from a wide variety of plant sources. Ethyl alcohol is used as a fuel, as an antiseptic, as a solvent for perfume and drugs, in flavoring extracts, in pharmaceutical products, and in the synthesis of ether used for anesthesia. It is the most important industrial solvent after water.

Methyl alcohol, used in the manufacture of organic compounds, is obtained from the *destructive distillation* of wood. It is used as a solvent in lacquers, varnishes, and polishes. Consumption of methyl alcohol can result not only in blindness because of sensitivity of the optic nerve to methyl alcohol, but it can also be fatal. Point out to your students that methyl alcohol was once used in automobile radiators as an antifreeze (because of its low freezing point). However, production for this purpose was halted since methyl alcohol is volatile and lethal. Current research is underway to explore the uses of methyl alcohol as a fuel for internal combustion engines. Many professional race cars run on methyl alcohol. You may wish to have your students do additional research on the future of methyl alcohol as a substitute fuel.

Although not a fermented or distilled alcohol, glycerol (also known as glycerine) is obtained as a by-product from the manufacture of soap. Glycerol (classified as a polyhydroxy alcohol) and ethyl alcohol are very similar in chemical behavior. For further discussion of glycerol see section *O-26*.

EXPERIMENT
O-25 COMPARING SOLUBILITIES

The purpose of this experiment is to compare solubilities of organic and inorganic compounds in water and various organic solvents. Students should compare the solubility of inorganic compounds with water and organic compounds with organic solvents. The immiscibility of polar and nonpolar solvents in each other is evidence that enables students to conclude that water is "unique" when compared with other solvents.

Concepts

- Like tends to dissolve like.
- There are two basic types of solvents, polar and nonpolar.
- Some organic compounds are not soluble in organic solvents.
- Many inorganic compounds are not soluble in water.
- Solubility is a relative concept. The basis for determining whether something is soluble often depends on the analytical method used to determine solubility or the sophistication of the determination; for example, 5 ppm, the solubility of PCB in blood, is a high solubility, whereas 5 g of another substance dissolved in 1 liter of H_2O would be a low solubility.

Objectives

- Test common materials for their solubility in water and organic solvents to determine whether they are organic or inorganic.
- Criticize the statement "like dissolves like" on the basis of observations of solubility.

Prelab Discussion Stress that unless the same quantities of solvent and solute are used, no meaningful comparison can be made.

Estimated Time One period

Student Grouping Pairs

Materials

60 13 x 100-mm test tubes
15 test-tube racks
150 cm^3 water
150 cm^3 toluene
150 cm^3 alcohol (ethanol)
20 g sodium chloride
20 g sugar (sucrose)
20 g *para*-dichlorobenzene
20 g calcium carbonate
150 cm^3 *n*-hexane *or* petroleum ether (Skelly B, b.p. 60–80°C)
15 graduated cylinders, 10 cm^3
15 spatulas

Advance Preparation None

Laboratory Safety Ensure adequate ventilation. Be certain there are no flames burning in the laboratory.

Range of Results The following results are to be expected:

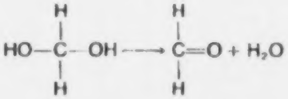
	Toluene	*Ethyl Alcohol*	*Petroleum Ether*	*Water*
NaCl	I	I or slightly S	I	S
Sugar	I	I or slightly S	I	S
$CaCO_3$	I	I	I	I or slightly S
p-dichlorobenzene	S	slightly S	S	I

Postlab Discussion The students should record their observations in table form as being either soluble, slightly soluble, or insoluble. Discuss with students why and how they obtained their results. Explain that ethyl alcohol has both a polar portion and a nonpolar portion and, therefore, is a good solvent for both polar and nonpolar solutes.

O-26 POLYALCOHOLS

Begin your lesson by calling attention to the structural formula for ethylene glycol (page 42). Instruct your students to examine this formula and then have them compare the formula with the one for ethyl alcohol (page 35). What is one major difference between the formula for ethylene glycol and the formula for ethyl alcohol? (Ethylene glycol is a *dihydroxy* alcohol.)

You can extend your lesson by pointing out that one class of alcohols not mentioned in the student text is that containing more than one —OH group attached to the same carbon atom. Alcohols of this type are known as *geminal diols*. Chemists have found these alcohols difficult to isolate because they easily break apart into water and a carbonyl-containing compound.



$$HO-\underset{H}{\overset{H}{C}}-OH \longrightarrow \underset{H}{\overset{H}{C}}=O + H_2O$$

Having discussed polyalcohols in general, return to your investigation of ethylene glycol. Suggest to your students that they carry out the following activity to determine the differences (if any) in freezing and boiling points of water and ethylene glycol.

Miniexperiment Add 100 cm^3 water to a beaker. Add a solution consisting of 100 cm^3 water and 25 cm^3 ethylene glycol to another beaker. Place the two beakers in the freezing compartment of a refrigerator. Leave them overnight. Checking the following day, what do you observe? Repeat this experiment with thermometers inserted in the water and in the solution. Check the thermometer readings the next day. What is the difference between the "freezing" points? Ask your students to devise a method to determine the boiling points of the two substances.

Conclude this section by indicating other uses of polyalcohols, and as an additional activity, have your students check ingredients on household product labels for common polyalcohols.

EVALUATION ITEMS

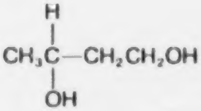
These are additional evaluation items that you may wish to use with your students at various times during the preceding section. The correct answer to each question is indicated by shading.

1. The compound that would have the highest boiling point is:

A. CH_4
B. CH_3CH_2OH
C. CH_3OCH_3
D. $CH_3CH{=}CH_2$

2. The compound capable of forming the largest number of hydrogen bonds is:

A. CH_3OCH_3
B. CH_4
C. CH_3OH
D.



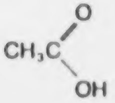
$$CH_3\underset{OH}{\overset{H}{C}}-CH_2CH_2OH$$

3. Since paraffin is a nonpolar compound, it would most likely dissolve in

A. distilled water.
B. toluene.
C. methanol.
D. salt water.

4. The compound most likely to dissolve in decane ($C_{10}H_{22}$) is:

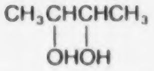
A. CH_3OH
B. H_2O
C. $CH_3(CH_2)_6CH_2OH$
D.

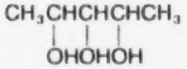


5. The high boiling point of water is due to its

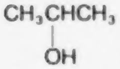
A. hydrogen bonding.
B. high molecular weight.
C. nonpolar properties.
D. impurities.

6. Which of the following is a dihydroxy compound?

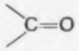
A. 
$CH_3\underset{\overset{|}{OH}}{CH}\underset{\overset{|}{OH}}{CH}CH_3$

B. 
$CH_3\underset{\overset{|}{OH}}{CH}\underset{\overset{|}{OH}}{CH}\underset{\overset{|}{OH}}{CH}CH_3$

C. CH_3OH

D. 
$CH_3\underset{\overset{|}{OH}}{CH}CH_3$

7. Complete the following chart:

	Functional group	*Functional group name*	*Structural group formula*	*Compound class*
a.	OH	______	______	______
b.	______	formyl	______	______
c.	______	______		______
d.	______	______	______	acid

See table on page 38 of the student module for answers.

SUGGESTED READINGS

"Industrial Alcohol from Waste Paper." *Chemistry*, November 1971, p. 23.

"Methanol—Solution for the Energy Crisis." *Chemistry*, April 1974, p. 24.

Monick, John A. *Alcohols: Their Chemistry, Properties and Manufacture*. New York: Van Nostrand Reinhold, 1968.

Ries, S. K., et al "Triacontanol: A New Naturally Occurring Plant Growth Regulator." *Science*, March 25, 1977, pp. 1339–344.
Description and discussion of an alcohol which helps regulate plant growth.

Wigg, E. "Methanol as a Gasoline Extender: A Critique." *Science*, November 29, 1974, pp. 485–90.

SUGGESTED FILMS

Alcohols. Color, 30 minutes. Encyclopaedia Britannica Educational Corp., 425 N. Michigan Ave., Chicago, IL 60611. Studies the relationship between alcohols and hydrocarbons from a functional-group point of view.

Shapes and Polarities of Molecules. Color, 18 minutes. A CHEM Study Film. Modern Learning Aids, Division of Ward's Natural Science Establishment. Rochester, NY 14603.
The concept of molecule polarity is developed. Models showing polarity are used to explain differences in the chemical properties and reactivities of molecules.

Poisons and Chemical Warfare

You may wish to begin this lesson with a discussion of the meanings of *poisons* and *chemical warfare* and how they affect our lives. Try to avoid philosophical discussions as to when such agents should be used.

Attempt to answer the following question: What is a poison? You may wish to point out, in your discussion, that it is sometimes "how much" that makes a material poisonous. Also, some materials are poisonous to one person or animal while they may have no effect on others. Ask your students if they have had any experiences with poisoning or poisons and, if so, which chemical substances were involved. Relate this discussion to the materials presented in the student text.

Discuss the photo of the sea hare on page 43 of the student module pointing out the fact that some animals use a method of self-defense similar to this. Although not a poison as such, this ink serves as a protective measure for animals in defending themselves from potential predators. Ask students to suggest names of other animals that protect themselves in a similar manner.

O-27 TEARS AND MORE TEARS

This section provides an opportunity to discuss the many different kinds of materials that irritate the mucous membranes in the body, often with lethal effects. Concentrate your discussion on the chemical makeup of these compounds and the physiological effects these compounds exhibit.

The equation for phosgene breakdown into carbon dioxide and hydrochloric acid is especially noteworthy due to the effects this breakdown has on the lungs and the respiratory system (see student module page 44). Peracyl nitrates (PAN) are harmful if introduced into the bloodstream.

BEST COPY AVAILABLE

Many of these chemical compounds are particularly harmful when inhaled by workers in manufacturing plants and industrial laboratories and have recently been found to be lethal. You may wish to have your students check current periodicals to find out where and why the majority of these work-related "accidents" occur such as in chemical laboratories, derailments of trains carrying chlorine gas, auto-manufacturing plants, steel mills, and fabric mills. Some students may wish to contact the EPA (Environmental Protection Agency, see section *O-6*) to find out what kinds of legislation are being undertaken to safeguard against these hazards. Can we produce the same products and cut down on the number of hazards?

O-28 ALKYLATING AGENTS

Alkylating agents react with proteins and nucleic acids—the important building blocks in the body. Often these compounds can destroy the proteins and nucleic acids and do permanent damage to the body.

Focus your students' attention on the equation for an alkylating agent which reacts with a body protein to produce a foreign protein. These foreign proteins will trigger the body's defense mechanisms, destroy tissue, or prevent key chemical reactions from taking place in the body.

When poisons react in the tissues of the body they produce acids and bases which can break down protein molecules. These reactions break the peptide linkage in the molecules, and the protein is not able to carry out its original function. (See discussion of hydrolysis in *Molecules in Living Systems: A Biochemistry Module.*) With severe exposure such breakdown continues until the entire tissue is destroyed.

Continue the discussion by pointing out the structural formula for chloroacetophenone, normally a solid which readily sublimes, thereby having longer lasting effects on those body tissues and cells it attacks. Compare the structure of chloroacetophenone to those of chloropicrin and *o*-chlorobenzalmalononitrile. Discuss the structural differences and similarities of each. How many chlorine and nitrogen atoms are present, and at what positions of the benzene ring are they attached? Discuss the ways in which the body maintains its delicate balance when attacked by these alkylating agents and what kind of measure it uses for this protection.

Of the alkylating agents, the mustard gases are some of the most powerful (see structures pages 45–46 of the student module). Compare these structures by examining the atoms that comprise each of them, noting any similarities to and/or differences from previously studied structures.

An interesting irony exists with regard to the use of the mustard compounds. Today they are principally used in the treatment of cancer as opposed to their previous use as war gases. Paradoxically, all those alkylating agents used in cancer chemotherapy are themselves powerful carcinogens. You may wish to have students research this topic comparing the compounds that render bodily harm with those that are used in cancer treatment.

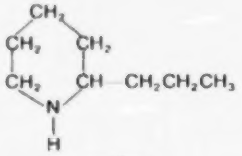
O-29 NERVE GASES

Nerve gases affect the nervous system by preventing cholinesterase (an enzyme) from breaking down acetylcholine, the compound responsible for the transmission of nerve impulses in a living organism. You may wish to discuss with your students the fact that when acetylcholine is not broken down (as normally occurs), the normal transmission of nerve impulses is disrupted and death usually results. The problem that actually arises when an impulse is transmitted is that the diaphragm is raised; when another impulse is not transmitted to lower the diaphragm, suffocation results.

These compounds are among the most toxic to humans as they are odorless and can penetrate the skin without damage or sensation and are lethal when they enter the bloodstream. These gases cause the respiratory muscles to weaken, resulting in paralysis and eventual death.

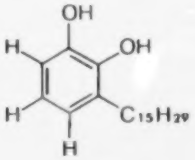
You can extend your discussion on poisons by referring to the material *Naturally-Occurring Poisons (Toxins)* on pages 127–129 of the appendix in the student module. Interested students may wish to find out about other kinds of poisons and how they affect the human body. What types of poisons (poisonous compounds, plants, or animals) are present in your community? What precautions should be observed? Of the plants containing chemicals which are toxic to humans are poison ivy, poison oak, and poison hemlock. You may wish to have interested students research this topic further.

You may wish to provide the chemical formulas of some of these poisonous compounds and compare them with others presented in this section. Coniine is one of the compounds in poison hemlock.



coniine

Urushiol is responsible for our unpleasant reactions to poison ivy and poison oak.



urushiol

In sections *O-34* to *O-37* of *Pesticides and Sex Attractants,* you will also be discussing chemical compounds (pesticides) that act similarly to nerve gases.

The use of poisons has a long historical and literary involvement. Can your students name any famous literary works in which poisons were used to do away with the leading characters or what historical figures met with death from poisoning? You may wish to work with the literature teacher on a joint project, or invite him or her to be a guest lecturer.

O-30 CHEMICAL WARFARE IN THE ANIMAL WORLD

You might introduce this section by having your students observe the behavior of a ladybug. (The ladybug is possibly "out of season" in your community, but you can obtain the insect from a biological supply house or garden-supplies outlet.) Ask several students to hold ladybugs carefully, but firmly, between their fingers for a minute or two and then to let them go. Have the students observe their fingers. In all likelihood, your students will find yellow stains on their fingers. What is the reason for this secretion?

Discuss the photos on page 47 of the student module. What substance does each animal secrete as its means of protection? Are these necessarily the most effective means of protection? How do other animals react to these defense mechanisms? Ask students to add to the list of animals named and pictured on this page other animals that possess similar types of defense mechanisms.

Some students may wish to investigate how the human body reacts to animal poisons such as snake venom. It might be interesting to discuss the treatment that is prescribed for humans who have come in contact with these poisons.

Pages 48 and 49 of the student module give several examples of other animals that use chemicals as a means of defense. Students will no doubt find this interesting reading. Discuss the fact that some research chemists have spent their entire careers studying animal defenses such as these. Throughout your discussion, stress the chemistry of the compounds used as means of protection. Another animal that uses a chemical defense method, the bombardier beetle, will be discussed in *Aldehydes and Ketones,* section *O-33.*

EVALUATION ITEMS

These are suggestions for evaluation items which you may wish to use with your students at various times during the preceding section. The correct answer to each question is indicated by shading.

1. Which of the following statements *is not* true concerning alkylating agents?

   A. They may act as mutagens and, therefore, cause changes in genetic material.
   B. They may act as carcinogens and produce abnormal growths.
   C. They are extremely reactive with proteins and nucleic acids.
   D. They are present in most insect sex attractants.

2. Which of the following elements is not found in lacrimators (chemical warfare agents)?

   A. nitrogen B. sulfur C. chlorine D. potassium

3. What is a poison?

4. Why do some animals and plants possess the ability to produce poisons?

5. List as many beneficial uses for poisons as you can.

6. Choose a poison and explain how it reacts chemically in the human body. Use chemical formulas and equations in your explanation if you can.

SUGGESTED READINGS

Arehart-Treichel, Joan. *Poisons and Toxins.* New York: Holiday House, Inc., 1976.
Reveals the dangers to humans of suicide and warfare poisons and toxins derived from microbes, garden plants, venomous animals, and household and garden chemicals.

Bebie, Jules. *Manual of Explosives, Military Pyrotechnics, and Chemical Warfare Agents.* Boulder, CO: Paladin Press, 1977.

Burchenal, Joseph H., and Burchenal, Joan R. "Chemotherapy of Cancer." *Chemistry,* July/August 1977, pp. 11–17.

Caras, Roger. *Venomous Animals of the World.* Englewood Cliffs, NJ: Prentice-Hall, Inc., 1974.

"Carcinogens in the Work Place, Where to Start Cleaning Up." *Science,* September 23, 1977, pp. 1268–269.

Cookson, John, and Nottingham, Judith. *Survey of Chemical and Biological Warfare.* New York: Monthly Review Press.

"Dioxin Toxicity Data Sent to Aid Italy." *Science News,* December 4, 1976, p. 359.
Dioxin, a by-product of the synthesis of hexachlorophene (an antibacterial chemical), is one of the most toxic chemicals known. Research has been devoted to the detoxification of this chemical in an effort to clean up several incidents of environmental contamination.

"Drinking Water: Another Source of Carcinogens." *Science,* November 29, 1974, pp. 485–90.

Halstead, Bruce W. *Dangerous Marine Animals.* Cambridge, MD: Cornell Maritime Press, Inc., 1959.

———. *Poisonous and Venomous Marine Animals of the World.* Princeton, NJ: Darwin Press, 1978.

Miller, Julie Ann. "Cancer Clues from Chemical Structures." *Science News,* June 4, 1977, pp. 362–63.
Examination of the theory that chemical carcinogens have a common characteristic related to chemical structure.

Watkins, T. F., et al. *Chemical Warfare, Pyrotechnics and the Fireworks Industry.* Elmsford, NY: Pergamon Press, Inc., 1968.

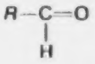
Aldehydes and Ketones

The next higher oxidation state of carbon above the hydroxyl group is carbon double-bonded to an oxygen atom yielding the carbonyl group. Use the discussion and photograph on page 50 of the student module to introduce these two classes of oxidized hydrocarbons.

You may wish to prepare your students for further discussion of the application of the aldehyde- and the ketone-containing compounds to everyday life by having several of them find out more about the uses of these compounds. Ask them to collect any information on names, uses, formulas, or molecular structures that they can find and bring these to class for discussion.

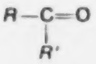
O-31 THE CARBONYL CLAN

The carbonyl group is found in two classes of compounds, the aldehydes and the ketones. Aldehydes are represented by the general formula



$$R-\underset{\underset{H}{|}}{C}=O$$

and the ketone group is shown as

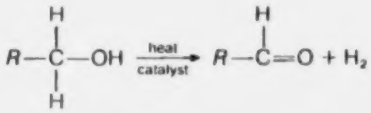


$$R-\underset{\underset{R'}{|}}{C}=O$$

(The *R* and *R'* may be the same or they may be different.)

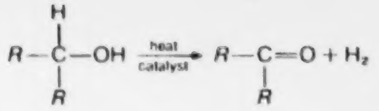
The major difference is that the hydrogen atom of the aldehyde group is replaced by a carbon-containing group in the ketone. Alcohols can be converted to aldehydes and ketones by oxidation (the loss of hydrogen). To discuss in more detail the formation of aldehydes and ketones from alcohols, you may wish to review the concept of primary, secondary, and tertiary alcohols introduced in *O-20* to *O-26* of this guide.

Any primary alcohol will yield an aldehyde upon oxidation.



$$R-\underset{\underset{H}{|}}{\overset{\overset{H}{|}}{C}}-OH \xrightarrow[\text{catalyst}]{\text{heat}} R-\overset{\overset{H}{|}}{C}=O + H_2$$

Similarly, the oxidation of any secondary alcohol will yield a ketone.

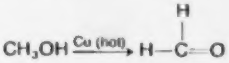


$$R-\overset{H}{\underset{R}{C}}-OH \xrightarrow[\text{catalyst}]{\text{heat}} R-\underset{R}{C}=O + H_2$$

A tertiary alcohol does not yield to oxidation unless the conditions are severe; the products in this case would be CO_2 and H_2O.

Focus attention on the examples of aldehydes and ketones given on page 51 of the student module, and then discuss the synthesis of formaldehyde. Use of *structural* formulas in showing the chemical change of methyl alcohol to formaldehyde may be more advantageous than simply using the *molecular* formulas given.

Demonstration: Place 10–20 cm³ of methanol in a 50-cm³ beaker. Heat a piece of copper metal to glowing in a Bunsen flame. Plunge the copper into the methanol, and then allow a student to carefully smell the vapor given off. It will smell of formaldehyde.



$$CH_3OH \xrightarrow{\text{Cu (hot)}} H-\overset{H}{C}=O$$

Pour a small sample of acetone into a beaker and allow several students to smell it. Some of them might recognize the smell of acetone as being the same as fingernail polish remover, cleaning liquids, or paint remover.

Demonstration The following is a simple demonstration of the properties of acetone as a solvent. Pour 20 cm³ of acetone into a large beaker, and then drop a Styrofoam cup into the beaker. Students will enjoy watching the cup "sink" and disappear.

You may wish to compare the dissolving properties of acetone and other solvents in a manner similar to that used in experiment *O-25*. You can initiate a short discussion as to why acetone is an effective solvent, comparing the structural formulas of acetone and other solvents that exhibit similar properties.

You may wish to have your students find out more about the commercial uses of aldehydes and ketones in addition to those mentioned in the student module.

If formula or molecular structures are available for any of the commercial products, pursue these in a manner similar to your discussion of *O-31*, and have students point out why each is classified as an aldehyde or as a ketone.

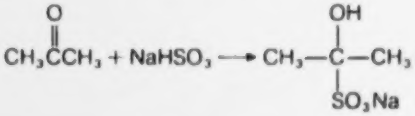
O-32 CARBONYL CHEMISTRY AND THE MILLIPEDE

Comparison of the C=C and the C=O bonds shows that both can undergo addition reactions. Examples of this type of reaction are given on pages 52 and 53 of the student module stressing that a number of groups can be added to the multiple bond. Examples of reagents that are added to the carbonyl bond include HCl, HBr, water, and the amines (section *O-44*).

Sodium bisulfite ($NaHSO_3$) is used in addition reactions to help determine if a compound is an aldehyde or a ketone. Since the addition product is often insoluble in concentrated sodium bisulfite solution, this can be used as a simple method for separating ketones and aldehydes from organic compounds which don't react with sodium bisulfite. The reaction is reversible (acid and base catalyzed) and the aldehyde or the ketone can be regenerated from the addition product. You can reinforce the concept involved in this reaction with the following classroom demonstration.

Demonstration You will need 50 g sodium bisulfite and 80 cm³ acetone.

Make up 120 cm³ of a saturated aqueous solution of $NaHSO_3$. Add approximately two volumes (80 cm³) stock solution to one volume (40 cm³) of acetone in a beaker. The solution will heat up. Point out the exothermic properties to your students. As the mixture cools, white crystals will appear, and the mixture will finally turn to a semisolid. Make up a 2:1 mixture of water: acetone (80 cm³ H_2O: 40 cm³ acetone). Have a student give each the "smell test." The acetone odor is clearly present in the comparison sample but not in the bisulfite reaction mixture. Point out that acetone *per se* no longer exists in the bisulfite reaction mixture.



$$CH_3\overset{O}{\overset{\|}{C}}CH_3 + NaHSO_3 \longrightarrow CH_3-\overset{OH}{\underset{SO_3Na}{C}}-CH_3$$

Have your students examine the reaction equation of acetone being reduced to 2-propanol by the addition of hydrogen to the carbonyl group (see student module page 53). Discuss this reaction in comparison to the formation of the carbonyl group by oxidation of the secondary alcohol. Oxidation and reduction are opposite processes, hence, the interconversion of ketone to alcohol and vice versa.

Students interested in the life sciences may wish to find out and explain how the human body converts ethyl alcohol to acetaldehyde and eventually breaks it down into CO_2 and H_2O.

O-33 THE BOMBARDIER BEETLE

Point out to your students that hydroquinone is oxidized to benzoquinone, and explain why H_2O_2 is reduced to H_2O when the bombardier beetle releases its defensive spray. Compare this oxidation-reduction reaction to the reaction involving the oxidation of methyl alcohol to formaldehyde in section *O-31*.

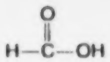
Hydroquinone is used in photography as a *developer*. As a reducing agent, it reduces silver bromide (AgBr)—only those grains on the film that have been exposed to light—to silver metal (Ag). In doing so, it is oxidized to benzoquinone. Unreacted (unreduced) silver bromide grains are then removed by washing with hypo (sodium thiosulfate—$Na_2S_2O_3$) which forms a soluble complex with AgBr and allows it to be washed away.

$$\underset{\text{(water insoluble)}}{AgBr + Na_2S_2O_3} \longrightarrow \underset{\text{(water soluble)}}{Na_3Ag(S_2O_3)_2 + NaBr}$$

At this point you might introduce some simple nomenclature of aldehydes and ketones. Name compounds such as acetone (2-propanone) and methyl ethyl ketone (2-butanone). Discuss the fact that the endings *-one* and *-al* refer to the ketone and the aldehyde functional groups, respectively.

Aldehydes and ketones are also derived from organic acids. Acetone, at one time, was commercially made from acetic acid that is found in vinegar (5 percent acetic acid and 95 percent water). *Acetum* from the Latin means "vinegar."

Formaldehyde, from the French *fourmi* meaning ant, is a derivative of formic acid.



$$H-\overset{\overset{\displaystyle O}{\|}}{C}-OH$$

The acid was first isolated from ants and is one of the irritants in bee stings.

EVALUATION ITEMS

These are suggestions for evaluation items which you may wish to use with your students at various times during the preceding section. The correct answer to each question is indicated by shading.

1. Differentiate between alcohols and aldehydes and ketones.

   Alcohols contain a hydroxyl group while aldehydes and ketones contain a carbonyl group.

2. Explain the significance of functional groups in organic reactions.

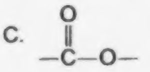
   They are the portions of the molecule that undergo the reactions; they are the "reaction sites."

3. Which of the functional groups is the hydroxyl group and which is the carbonyl group?

   hydroxyl __A__

   carbonyl __D__

   A. $-OH$

   C.  $-\overset{\overset{\displaystyle O}{\|}}{C}-O-$

   B. $O{=}C{=}O$

   D. $>C{=}O$

4. What does the letter *R* represent when used in writing structural formulas for aldehydes and ketones, and why is it used?

   R represents the non-functional group portion of the molecule. It is used to avoid having to write large structures.

5. Which equation represents the oxidation of an alcohol to its highest oxidation state?

   A. $CH_3OH \longrightarrow CH_4 + H_2O$
   B. $CH_3OH \longrightarrow CH_2O + H_2$
   C. $CH_3OH \longrightarrow CH_2O_2 + H_2$
   D. $CH_3OH \longrightarrow CO_2 + H_2O$

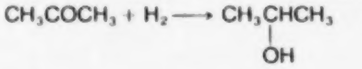
6. What effects on miscibility with water would lengthening the *R* group of an aldehyde have? Would there be a similar effect if the ketone *R* group was

lengthened? Explain your reasoning. How does this compare with the *R* groups of alcohols?

Any increase of *R* (a nonpolar portion of the molecule) will result in lowering its solubility in a polar solvent, but will increase its solubility in a nonpolar solvent.

7. State whether oxidation or reduction is occurring in the following equations:

a. $CH_3OH \longrightarrow CH_2O + H_2$ *oxidation*

b. 
$CH_3COCH_3 + H_2 \longrightarrow CH_3\underset{\underset{OH}{|}}{C}HCH_3$ *reduction*

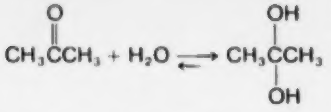
8. Describe what an addition reaction is, and tell why this is possible with aldehydes and ketones.

Addition means that a group has been added—this occurs at sites of unsaturation such as double bonds. Because aldehydes and ketones contain double bonds, they may undergo addition reactions.

9. Explain why acetone is miscible with water.

A polar carbonyl group hydrogen bonds to the water.

10. Predict where the equilibrium will lie:


$CH_3\overset{\overset{O}{\|}}{C}CH_3 + H_2O \rightleftharpoons CH_3\overset{\overset{OH}{|}}{\underset{\underset{OH}{|}}{C}}CH_3$

See Polyalcohols, section *O-26*

SUGGESTED READINGS

Aviado, Domingo, et al. *Isopropanol and Ketones in the Environment* (*Solvents in the Environment* Series). Cleveland, OH: CRC Press, Inc., 1977.

Johnson, F. H., and Shimomura, O. "Bacterial Aldehydes and Other Luciferins." *BioScience*, November 1975, pp. 718–22.

SUGGESTED FILM

Synthesis of an Organic Compound. Color, 22 minutes. A CHEM Study Film. Modern Learning Aids, Ward's Natural Science Establishment, Rochester, NY 14603. Synthesis of a ketone from an alcohol.

Pesticides and Sex Attractants

The use of pesticides, today a highly controversial subject, is a part of the story of human survival. Begin with a discussion to determine your students' understandings of what pesticides are and why they are used. Questions such as the following can be used for class discussion:

1. What is an insect "pest"?
2. Why do you think insects are considered to be pests more than other groups of animals?
3. What are both the beneficial and the harmful aspects of insects?
4. What are the beneficial and the harmful aspects of eliminating insect pests?
5. What are some of the insect pests in your local area?

If any of your students collect insects, you may wish to invite them to bring in their collections and insect books to give other students an opportunity to observe some of the variety that exists among insects (or perhaps your biology department has collections which you may borrow). You might present a film such as *Introducing Insects—Butterflies, Beetles and Bugs**, or *Insects** to round out the students' understanding that insects do have a vital place in the natural world.

In anticipation of this unit, students can write to the U.S. Department of Agriculture, the U.S. Environmental Protection Agency, state agricultural facilities, university agriculture and zoology departments, and visit their library resource center for information about helpful and harmful insects, insecticides, and the effectiveness of various chemical compounds in controlling pests. Through some of the same sources, students may also be able to obtain information and case histories on use of sex attractants as a means of

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*See *Selected Readings and Films* list in the appendix of this guide for further information.

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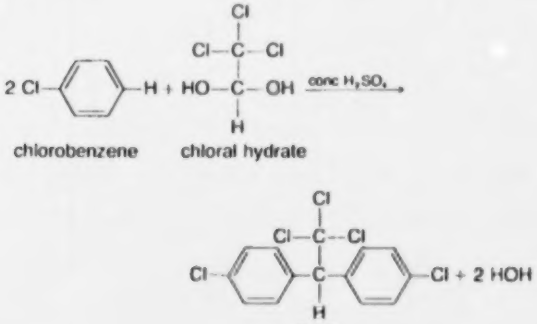
pest control. Encourage them to share information and thoughts about these topics with their classmates.

O-34 INSECTICIDES: CHLORINATED HYDROCARBONS

You may wish to briefly discuss with your students the history of pesticides—the chemical substances used to control insects before the discovery of DDT in 1938. The ancient Greeks used sulfur against insects, while Marco Polo brought pyrethrum to Europe from the Far East to combat these pests. Over one hundred years ago organic compounds such as nicotine sulfate and creosote were used to control insects, and other inorganic compounds, such as arsenic compounds (lead arsenate), hydrogen cyanide, copper sulfate, and compounds of mercury were also used. All of these substances presented problems; they did not work very well against insects, and they were very toxic to humans and animals. In 1939, Paul Mueller discovered that the chlorinated hydrocarbon, DDT (first synthesized in 1874), was effective in killing houseflies and moths.

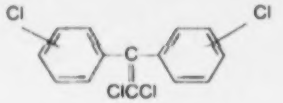
Some of the better-known pesticides today are the synthetic chlorinated hydrocarbons. Chlorinated-hydrocarbon insecticides contain chlorine which, like hydrogen, forms a single bond and can be substituted for hydrogen in specific hydrocarbons. DDT, the most commonly known example, is easily synthesized from cheap, readily available chemicals. You may wish to discuss this with your students using the following equation:



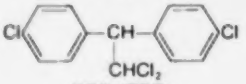
chlorobenzene chloral hydrate

DDT

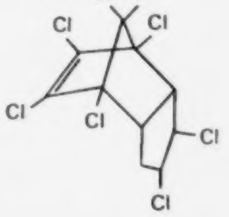
Use the following structures of chlorinated-hydrocarbon pesticides, as well as the structures on pages 58–60 of the student module, in discussing the characteristics of these compounds and how they are formed. Compare the similarities and differences of each structure.



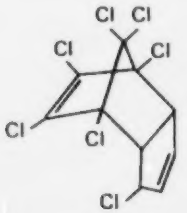
DDE



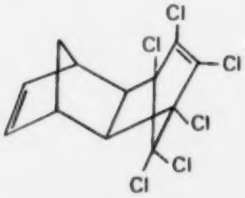
DDD (TDE)



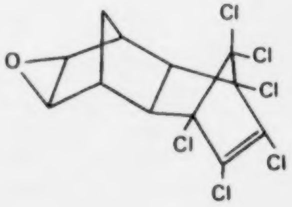
chlordane



heptachlor



aldrin



endrin

The major problem with chlorinated-hydrocarbon compounds is the inability of nature to decompose them rapidly. Some of the following reasons will help to illustrate:

1. They do not occur naturally in our environment.
2. The carbon-chlorine bond is very stable.
3. These compounds do not react with other chemicals found in soil or with water.

Therefore, chlorinated hydrocarbons are persistent and have a long life span—15 to 20 years—

without decomposing. To add to this problem, the most common of these compounds, DDT, eventually breaks down to produce other chlorinated hydrocarbons (DDE and DDD) which also have long life spans.

We have noted before that chlorinated hydrocarbons, particularly DDT, are not water soluble. Note that the structure of carbon tetrachloride, CCl_4 (used as a dry-cleaning solvent to dissolve fats—grease), is similar to that of DDT. Based on this, one might assume that DDT would be soluble in fats, which it is. It should now be easy to see why DDT accumulates in the fatty tissue of man and animals. It is this fat-soluble nature which causes the accumulation of DDT in food chains to be magnified. Another reason for their persistence and widespread occurrence is that chlorinated hydrocarbons are easily carried through the air and by water, thus enabling them to be transmitted all over the world to places where people have never used them. Using the illustration of a food chain on page 59 of the student module, discuss the successive stages which result in the accumulation of a chemical substance that is resistant to breakdown, such as DDT. Students may wish to suggest other examples that illustrate this same concept.

The concentration of these hydrocarbons in the food chain often shows a tenfold increase with each succeeding step in the chain. You may wish to share with your students this example of the magnification problems that result from the pesticide DDT in one specific food chain.

	*DDT Residues ppm**
Water	0.00005
Plankton	0.04
Silverside minnow	0.23
Sheephead minnow	0.94
Pickerel (predatory fish)	1.33
Needlefish (predatory fish)	2.07
Heron (feeds on small animals)	3.57
Tern (feeds on small animals)	3.91
Herring gull (scavenger)	6.00
Fish hawk (osprey) egg	13.80
Merganser (fish-eating duck)	22.80
Cormorant (feeds on larger fish)	26.40

*ppm = parts per million of total residue.

The table is from "DDT Residues in an East Estuary: A Case of Biological Concentration of a Persistent Insecticide" by G. M. Woodwell et al. From *Science*, Vol. 156, May 12, 1967; copyright 1967 by the American Association for the Advancement of Science.

Refer to the photographs on page 59 and have students who have found out more about the history of DDT, its applications, and its problems lead a discussion of its effects on health and food productivity throughout the world. For all of the benefits DDT has provided by eliminating insects, its usage has also created many problems which you may wish to review with your students.

1. Most chlorinated hydrocarbons have been found to be carcinogenic.
2. They can be quite disruptive to the body's enzymes.
3. They cause reproductive problems in birds, mammals, and fish.
4. They can kill birds, mammals, and fish upon ingestion (but do not seem to be lethal to humans).

The effects of pesticide control make "news" fairly often. You may wish to have students check newspapers and magazines for articles on pesticides and photographs similar to those on pages 59 and 61 which they can bring to class for discussion or use in the construction of a collage.

Miniexperiment Have your students copy the names of compounds from labels on pesticide cans or boxes found in the home and bring this list to class. (Also ask them to copy the names of pests these products are intended to kill.) Students might obtain similar data on other insecticides by visiting a nearby nursery, or garden center.

Caution students that pesticide products should be handled carefully even though they are in sealed containers.

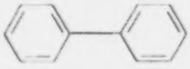
Have students compare lists and make a tally of the different compounds that are found. This should give them some indication of how common these compounds are in our everyday life.

O-35 CHLORINATED HYDROCARBON PROBLEMS

Polychlorinated hydrocarbons (PVCs and PCBs) have many industrial uses but also have emerged as environmental troublemakers in recent years.

Polyvinyl chloride (PVC), a good substitute for rubber, has vinyl chloride as its base. Discuss with your students the problems caused by this chemical. You may wish to have your students find out more about the uses and the problems of PVCs through their library resource center.

The group of PCBs includes at least forty to fifty compounds (molecular structure on page 61 of the student module). Show your students how these compounds are formed by changing the number and the positions of chlorine atoms on the biphenyl.



One of the most common uses of PCBs is as a plasticizer. PCBs are used as additives that have softening effects when added to certain compounds; the result is flexibility in some materials, and in others, the ability to be formed or molded into different shapes. As you discuss some of these problems with your students, point out that chemists are hard at work trying to synthesize safer compounds to replace these while keeping the useful properties that are needed in our industrial society.

O-36 BAN ALL INSECTICIDES?

Scientists are continually trying to develop insecticides that are not only safer than but are as effective as—if not better than—the substances being replaced. Use a table similar to *Some Synthetic Chemical Pesticides* which follows, to group the pesticides for further discussion. Suggest that several students find out which of these pesticides are now banned for use in the United States. Other students may wish to find out what, if any, new synthetic pesticides have been developed.

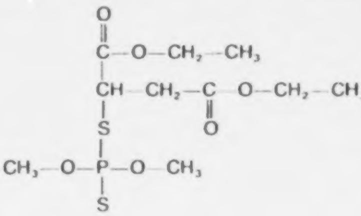
Some Synthetic Chemical Pesticides

Class	*Relative Cost*	*Relative Persistence*
Organophosphates	expensive	short
Malathion		
Parathion		
TEPP		
Carbamates	expensive	short
Carbaryl		
Baygon		
Chlorinated Hydrocarbons	cheap	long
Aldrin		
BHC		
Chlordane		
Dieldrin		
DDD		
DDT		
Endrin		
Mirex		

Some pesticides, such as the organophosphates, were developed from studies on the effects of nerve gases used during World War II. These pesticides are very toxic to mammals, including humans—especially those who work in or near sprayed areas. The organophosphates are relatively nonpersistent in the environment and act as nerve poisons. Review with your students the discussion of nerve poisons in section *O-29* focusing on acetylcholine which is responsible for the transmission of nerve impulses in an organism. Organophosphates act as nerve gases and inhibit the activity of the enzymes that allow acetylcholine to work. This leads to the death of the organism.

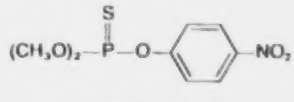
Two common commercial organophosphates are parathion and malathion. Parathion is an insecticide that is more poisonous, but less persistent, than the chlorinated hydrocarbons. This is because of its rapid decomposition in the environment. (See student module page 61 for structural formula of parathion.)

An organophosphate that is less toxic than parathion is malathion. You may wish to discuss its structural formula with your students comparing its formula to that of parathion.

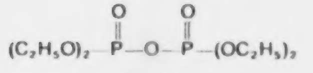


malathion

Organophosphates are rarely found in food chains because they break down easily. Several other organophosphates which you may wish to discuss with your students are listed below.

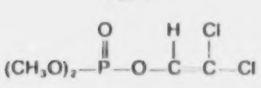


methyl parathion



$$(C_2H_5O)_2-\overset{\overset{O}{\|}}{P}-O-\overset{\overset{O}{\|}}{P}-(OC_2H_5)_2$$

TEPP

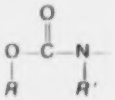


$$(CH_3O)_2-\overset{\overset{O}{\|}}{P}-O-\overset{\overset{H}{|}}{C}=\overset{\overset{Cl}{|}}{C}-Cl$$

DDVP

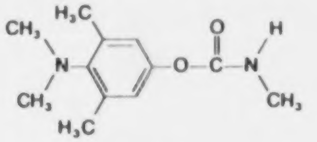
Ask some of your students to find out the types of insects each pesticide discussed in this section is aimed at controlling.

Another group of pesticide compounds developed after DDT was banned is the carbamates. This group of pesticides, of which carbaryl is the most important, is less toxic to mammals than the organophosphates. The important feature of this group of pesticides is the following molecular grouping

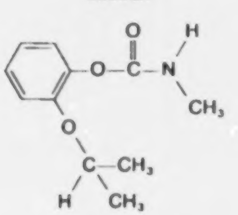


$$\underset{\underset{R}{|}}{O}-\overset{\overset{O}{\|}}{C}-\underset{\underset{R'}{|}}{N}-$$

Point out the structural formula for carbaryl in the student module on page 61. Two other carbamate pesticides are illustrated below. Ask your students to examine the formula for these and find the molecular grouping that characterizes this class of pesticides. What are these specific compounds intended to kill? How effective are they?



zectran



baygon

New pesticide compounds are always being researched and developed in chemical research labs across the country. Since the problems with DDT arose, these new potential synthetic pesticides must undergo careful testing before being put on the market for general use. Government agencies, such as the Food and Drug Administration, the National Cancer Institute, and the National Institutes of Health, test and monitor the toxicity and environmental effects of new pesticides.

Discuss the potential effects of entirely discontinuing the use of insecticides as an answer to the prevention of the poisoning and the polluting of the environment by these chemicals. Compare this solution to the possible results of widespread, indiscriminate use of chemicals that might destroy all insect pests. The next section, *O-37 Sex Attractants,* discusses an alternative method of insect control that has proven quite effective.

Suggested Readings In 1962, Rachel Carson, a biologist, published a bestseller book that met with both severe criticism and wide public acclaim and praise. The book, *Silent Spring,* detailed the harmful aspects of pesticide use in our environment. Students interested in this aspect of the environmental balance should be encouraged to read this book. Ten years later, the widespread use of DDT was banned in the United States.

Students may also be interested in reading the booklet published by the Dow Chemical Company that presents another point of view. *Silent Autumn: A Case for Pesticides and Farm Chemicals* (copyright 1977) can be obtained, free of charge, from Dow Chemical, Midland, MI 48640.

O-37 SEX ATTRACTANTS: AN ALTERNATIVE

Insects use sex attractants, or sex pheromones, as a means of attracting mates. These chemicals are very specific for each species. The power of a pheromone may be illustrated with the following example: The silkworm moth *(Bombyx mori)* can detect about one part pheromone in 10^{16} parts air, or, if wind conditions are right, one of these moths, giving off attractants at a rate of one microgram per second, can "call in" mates over a space measuring 5 kilometers long by 91 meters high by 182 meters wide.

Disparlure, the sex attractant of the gypsy moth discussed on page 64 of the student module, has been synthesized by the USDA. The amount they had stockpiled as of a few years ago—30 grams—is said to be enough to bait 60 000 gypsy-moth traps for 50 000 years.

Scientists have now found an alternative to the pollution caused by insecticides and the damage that is associated with these poisonous killing agents. Sex attractants are now being used to lure insects into traps for destruction or mass sterilization and release.

Many sex attractants are relatively simple esters (which we discuss in the next section of the student module), and many are closely related as in the case of these acetates:

Sex Attractant	*Insect*
trans-7-dodecenyl acetate	false coddling moth
cis-7-dodecenyl acetate	cabbage looper
cis-8-dodecenyl acetate	oriental fruit moth

Have your students check the structural formulas for the sex attractants mentioned above by using the student module appendix, pages 128–129. Some students may wish to read further about sex attractants as alternatives to pesticides. Suggest that they check their library resource center's recent periodicals for up-to-date information.

The USDA is testing yet *another* alternative to pest control. In early 1978 it began its first extensive test of the mosquito *Toxorhynachites rutilus rutilus,* which feeds on its biting and disease-carrying relatives in the larval stage. This mosquito is found in several of the southern states, but it does not reproduce very fast. Scientists at the USDA have found a way to "mass-produce" these insects. Some might ask if these mosquitos will get out of control like their relatives. Scientists do not forsee this occurring, since the biting mechanism of this mosquito cannot penetrate the skins of animals or humans. Also, its food is the nectar of a flower and plant, detritus. Some of your students may wish to check on this and other alternatives to pest control.

EVALUATION ITEMS

These are suggestions for evaluation items which you may wish to use with your students at various times during the preceding section. The correct answer to each question is indicated by shading.

1. Discuss the problems which have resulted from the use of chlorinated hydrocarbons and the cause of such problems.

   open-ended question—see student module pages 58–59

2. The main problem with DDT and other chlorinated hydrocarbons is their

   A. continuing concentration in each higher step of the food chain.
   B. extreme toxicity to humans.
   C. ability to act as alkylating agents.
   D. ability to reduce the viability of insects.

3. Discuss how sex attractants can be used for insect control.

   open-ended question—see student module page 63

4. What are the advantages of sex attractants over insecticides?

   see student module page 63

5. Discuss the results of eliminating all insects in your area. Are there "good" insects whose disappearance would affect the environment adversely? Are there "bad" insects that would also be missed? Why?

6. What are some of the difficulties encountered in testing new chemical compounds for their effectiveness as insecticides?

7. Discuss the following statement in relation to the ecological balance in our environment.

   In the early 1940's, enthusiastic supporters of DDT and other synthetic pesticides predicted the complete destruction of all insect pests.

8. If you were creating a pesticide, what would you consider to be the general characteristics of an ideal pesticide?

   open-ended question

9. What was done before the use of DDT to control pests?

10. Discuss the problem that arises when insects become resistant to a pesticide such as DDT.

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11. Are humans in any danger from the use of DDT? from other pesticides?
12. What possible problem(s) may result from the excessive use of a sex attractant to eradicate an insect pest?

SUGGESTED READINGS

"Aphids Foiled by False Alarm." *Chemistry*, July 1977, pp. 23–24.

Beroza, Morton. "Insect Sex Attractants." *American Scientist*, May/June 1971, pp. 320–25.
A general discussion of insect sex attractants with a special emphasis on the gypsy moth.

Beroza, Morton, and Knipling, E. F. "Gypsy Moth Control with the Sex Attractant Pheromone." *Science*, July 7, 1972, pp. 19–27.
A somewhat technical account of gypsy moth control techniques used by those directing the project.

Carson, Rachel. *Silent Spring*. Boston: Houghton Mifflin Company, 1962.

"Degrading Pesticides." *Chemistry*, June 1978, pp. 34–35.

"EPA Lists Restricted Farm Chemicals." *Farm Journal*, June 1977, p. A4.

Keller, Eugenia. "The DDT Story." *Chemistry*, February 1970, pp. 8–12. Reprint No. 92.

Marx, Jean L. "Insect Control: I. Use of Pheromones." *Science*, August 24, 1973, pp. 736–37; II. "Hormones and Viruses." *Science*, August 31, 1973, pp. 833–35.

Peakall, D. B. "Pesticides and the Reproduction of Birds." *Scientific American*, April 1970, pp. 73–74.
An account of how chlorinated hydrocarbons affect breeding behavior and reproduction in birds.

"Pesticides and Birds." *Chemistry*, September 1975, p. 20.

"Safe Insecticides." *Chemistry*, November 1977, p. 23.

Silent Autumn: A Case for Pesticides and Farm Chemicals. The Dow Chemical Company, 1977. (For a free copy, write to: Midland, Michigan 48640.)

Taking Things Apart & Putting Things Together. American Chemical Society. Washington, DC pp. 51–54.
History and discussion of a variety of insecticides which have enabled humans to control insect pests.

Williams, Carrol. "Third Generation Pesticides." *Scientific American*, July 1967, pp. 3–7.
A discussion of insect hormones. Special emphasis is given to the linden bug and its juvenile hormone mimic, juvabione.

Wurster, Charles F. "Aldrin and Dieldrin." *Environment*, October 1971, pp. 33–45.
An extended discussion of the health and environmental problems caused by these insecticides.

———. "DDT Goes to Trial in Madison." *BioScience*, September 1969, pp. 809–13.
Wurster's account of the DDT trial including the evidence submitted and the strategies used.

SUGGESTED FILMS AND FILMSTRIP

Films:

Cotton Insect Management. Color, 25 minutes. Chemagro, Division of Baychem Corp., Advertising Section, P. O. Box 4913, Hawthorn Rd., Kansas City, MO 64120.
While advocating a chemical control program for insect pests, this film also recognizes the importance of preserving beneficial insects.

Epidemiology of Pesticide Poisonings. Color, 19 minutes. U.S. National Audiovisual Center, General Services Administration, Washington, DC 20409. Attention: Order Section/RR.

The Insect War—Advances in Pest Control. Color, 40 minutes. Time-Life Films, Inc., 43 W. 16th St., New York, NY 10011.
Highlights some alternatives to general pesticides that are less hazardous to other living things.

Insects. Color, 11 minutes. Encyclopaedia Britannica Educational Corp., 425 N. Michigan Ave., Chicago, IL 60611.

Insects Harmful to Man. Color, 16 minutes. International Film Bureau, 332 S. Michigan Ave., Chicago, IL 60604.
Surveys the wide range of insects having a negative economic or health impact on humans.

Insects Helpful to Man. Color, 17 minutes. International Film Bureau, 332 S. Michigan Ave., Chicago, IL 60604.
Although the film surveys insects which are commercially and ecologically useful to humans, it focuses on the honeybee and the silkworm.

Introducing Insects—Butterflies, Beetles and Bugs. Color, 17 minutes. The National Film Board of Canada, 1251 Ave. of the Americas, New York, NY 10020.

More Than a Paycheck. 30 minutes. U.S. National Audiovisual Center, General Services Administration, Washington, DC 20409. Attention: Order Section/RR.
This film closely examines occupational environments which predispose workers to cancer, and describes the efforts being taken to minimize risk.

Perspectives on Pesticides. Color, 15 minutes. U.S. National Audiovisual Center, General Services Administration, Washington, DC 20409. Attention: Order Section/RR.

Pesticides in Focus. Color, 25 minutes. Shell Film Library, 450 N. Meridian St., Indianapolis, IN 46204.
Suggests that although there are alternative methods of pest control, they are not capable of replacing chemical pesticides. Film also records the painstaking research involved in development of insecticides that will be effective and yet have minimum hazard to other forms of life.

The Phaltan Story. Color, 21 minutes. Chevron Chemical Co., Ortho Division, 200 Bush St., San Francisco, CA 94104.
An account of the development and use of a fungicide on diseases of fruit.

Prescription For Safety. Color, 18 minutes. Chevron Chemical Co., Ortho Division, 200 Bush St., San Francisco, CA 94104.
Examines a sensible approach to the safe handling of pesticides.

The Rise and Fall of DDT. Color, 18 minutes. Time-Life Multimedia, Distribution Center, 100 Eisenhower Drive, Paramus, NJ 07652.

The Rival World. Color, 25 minutes. Shell Film Library. 450 N. Meridian St., Indianapolis, IN 46204.
Details of the endless struggle between insects and humans, and the applications of science that enable humans to compete successfully.

Unseen Harvesters. Color, 28 minutes. Motion Picture Section, Advertising Dept., E. I. du Pont de Nemours and Co., Inc., 1007 Market St., Wilmington, DEL 19898.
Illustrates the tremendous amount of time and money in research necessary to produce a new and safe agricultural chemical.

World of Insects. Color, 22 minutes. Chevron Chemical Co., Ortho Division, 200 Bush St., San Francisco, CA 94104. Shows a sample of insects that compete with man in the environment.

Filmstrip:

The Pesticide Problem. Two filmstrips and cassettes. *(Chlorinated Hydrocarbons; Organic Phosphates.)* BFA Education Media, Division of CBS Inc., 2211 Michigan Ave., P. O. Box 1795, Santa Monica, CA 90406.

Esters and Acids

Esters occur naturally in a diversity of forms including beeswax, sex attractants, and animal fats, yet they are known mainly for their pleasant fragrances. Many of the flavors and fragrances that we know today are derived from esters. Using the photograph on page 66 of the student module, discuss with your students the fact that esters were of interest to ancient civilizations such as the Egyptians. Fragrances at that time, and for many centuries afterwards, were largely derived from plants by means of a variety of extraction processes. Today, many of the fragrances that we are familiar with are chemically synthesized.

Some esters are used as solvents for industrial purposes and as components in photographic film. Other esters are employed in the synthesis of fibers for use in textiles (polyester, acetate, rayon), tire cords, and recording tapes. Some interested students may wish to find out about further uses of esters in industry and everyday life. Others might enjoy researching the history of perfumes, perfume-making, and modern perfume technology.

Esters are commonly produced by a condensation reaction between a carboxylic acid and an alcohol. The properties of an ester depend upon the ester's component acid and alcohol. For example, the acids and alcohols with increased hydrocarbon chain lengths are slightly soluble in water, and the resultant ester will also be slightly soluble in water.

Proceed with experiment *O-38,* discussing with students the esters that they will synthesize in the laboratory. This will serve as an introduction to the discussion of the chemical formation of esters and their uses.

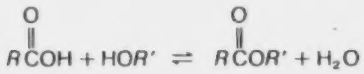
EXPERIMENT
O-38 PREPARATION OF ESTERS

This experiment gives students experience in preparing another type of organic compound, an ester, from an acid and an alcohol. In doing so, they will be able to note the change in properties that accompanies a chemical change—a change in odor from reactant to product.

Concepts

- An ester may be prepared by the reaction of an organic acid and an alcohol.
- The reaction of an alcohol with an acid to give an ester is an example of a very common type of reaction called condensation.
- Condensation reactions involve the uniting of two molecules to give a larger molecule and a small stable molecule (in this case, water).
- The product of the preceding reaction, an ester, has an odor completely different from that of the original reactants.
- The function of the sulfuric acid is twofold. It acts as a catalyst by protonating (furnishing a proton to) the acetic acid and making the acetic acid more reactive toward the alcohol. Secondly, sulfuric acid has a high affinity for water and removes it as it forms, allowing

the reaction to continue. Without the H_2SO_4, the reaction would be reversible:



$$R\overset{O}{\overset{\|}{C}}OH + HOR' \rightleftharpoons R\overset{O}{\overset{\|}{C}}OR' + H_2O$$

Objectives

- Demonstrate the preparation of a specific ester.
- Relate the odor of the ester obtained to common odors with which the students are familiar.

Estimated Time One period

Student Grouping Pairs

Materials

100 cm^3 glacial acetic acid
50 cm^3 *n*-pentyl alcohol (amyl alcohol)
50 cm^3 *n*-octyl alcohol
50 g salicylic acid
50 cm^3 methyl alcohol
30 18 x 150-mm test tubes
15 400-cm^3 beakers
15 10-cm^3 graduated cylinders
15 ring stands and rings
15 wire gauze, asbestos centers
15 Bunsen burners
15 clamps, universal

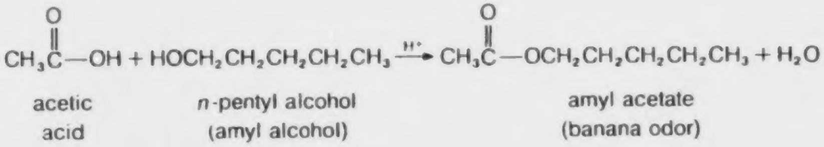
Advance Preparation None

Prelab Discussion The equations illustrating an esterification reaction should be introduced and related to the students' laboratory work.

Laboratory Safety Caution: *Warn students to handle the concentrated sulfuric acid (H_2SO_4) with care and to follow the proper technique for smelling odors as stated in Appendix I: Safety.*

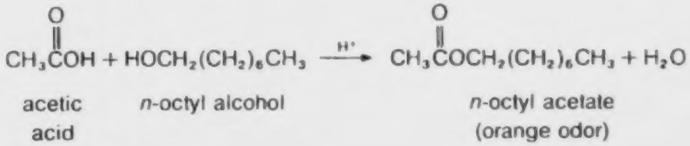
Laboratory Tips If an odor is not readily detectable directly from the test tube, pouring the contents into warm water should increase the intensity of the odor.

Postlab Discussion All groups should have obtained the same results. Write the following equations on the chalkboard showing the reactions that occurred in the experiment.



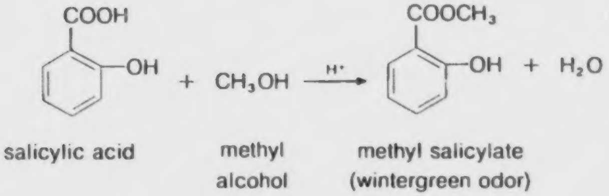
$$CH_3\overset{O}{\overset{\|}{C}}{-}OH + HOCH_2CH_2CH_2CH_2CH_3 \xrightarrow{H^+} CH_3\overset{O}{\overset{\|}{C}}{-}OCH_2CH_2CH_2CH_2CH_3 + H_2O$$

acetic acid
n-pentyl alcohol (amyl alcohol)
amyl acetate (banana odor)



$$CH_3\overset{O}{\overset{\|}{C}}OH + HOCH_2(CH_2)_6CH_3 \xrightarrow{H^+} CH_3\overset{O}{\overset{\|}{C}}OCH_2(CH_2)_6CH_3 + H_2O$$

acetic acid
n-octyl alcohol
n-octyl acetate (orange odor)



COOH
OH
+ CH₃OH
H⁺
COOCH₃
OH
+ H₂O
salicylic acid
methyl alcohol
methyl salicylate (wintergreen odor)

Any information obtained on the commercial production of these fragrances and their uses for flavorings or deodorizing aerosol sprays can be discussed at this time.

Using the structural formulas on pages 67 and 68 of the student module, point out the characteristic bonding properties of the ester group and the ending of the ester-compound names. (Several other organic structures for esters are presented on page 129 in the student module, *Appendix III.*)

You may wish to have students look at containers of items found in the home and that they suspect might contain esters. Have them list each item and its ingredients and bring the lists to class for discussion and possible comparison.

Draw student attention to the structural formulas of butyric acid and methyl butyrate found on page 68 of the student module. Point out that the difference between the two molecules is the replacement of the H atom in the acid by a methyl group in the methyl butyrate molecule. This seemingly small difference in structure converts one putrid smelling compound (butyric acid) to a compound that has the fragrance of an apple (methyl butyrate). Then point out that the elongation of the methyl group to a pentyl group, forming pentyl butyrate, results in an apricot scented compound.

O-39 ORGANIC ACIDS

The remainder of this chapter focuses on organic acids, specifically the carboxylic acid functional group. Draw the structural formula for the carboxylic acid group on the chalkboard, asking what previously studied compounds had this structure.

Organic acids may be derived from the reaction of a primary alcohol with oxygen, as is illustrated in the following equation.

$$CH_3CH_2OH + O_2 \xrightarrow{enzyme} CH_3COOH + H_2O$$

Ask your students to compare the structural formula of an aldehyde with the structural formula of an organic acid. Note that the addition of oxygen to an aldehyde will form an organic acid. The following reaction is an example of one that occurs in the human body, where acetaldehyde is converted to acetic acid.

$$\underset{\text{acetaldehyde}}{CH_3CHO} + \tfrac{1}{2}O_2 \xrightarrow{catalyst} \underset{\text{acetic acid}}{CH_3COOH}$$

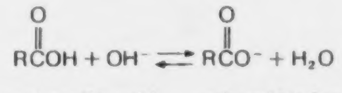
Stress that carboxylic acids are in a higher oxidation state than either alcohols or aldehydes due to the fact that the carbon atom of the carboxyl group is doubly and singly bonded to oxygen atoms.

Further study of the organic acids may be made by examining their characteristic physical properties. Compare the strength of organic acids to the strength of inorganic acids mentioned in the student module by performing the following miniexperiment.

Miniexperiment *Strengths of Organic and Inorganic Acids:* Obtain pH meters, universal pH paper (wide-range), *or* a series of indicator solutions as suggested in *P-38, Communities of Molecules: A Physical Chemistry Module.* You can have your students prepare solutions of the *same concentration* (e.g., 0.1 M *or* 0.01 M) of a variety of organic and inorganic acids. Compare the pH values of the various solutions, and discuss the results. Which of the acids are strong? Which are weak?

When discussing why some acids are stronger than others, you may wish to refer to previously studied concepts such as bonding, electronegativity, and polar vs. nonpolar bonding. Further information on these topics may be found in other modules.

Many carboxylic acids are weak acids, that is, they ionize only slightly in water, resulting in the carboxylate ion formation.



$$\underset{\text{carboxylic acid}}{R\overset{\overset{O}{\|}}{C}OH} + OH^- \rightleftharpoons \underset{\text{carboxylate ion}}{R\overset{\overset{O}{\|}}{C}O^-} + H_2O$$

carboxylic acid   carboxylate ion

However, they will react with strong bases (sodium hydroxide, for example) to form salts which are water soluble due to their ionic characters. Examine the chemical reactions in the student module on pages 69 and 70 for examples of this type of reaction. Salicylic acid, a relatively weak acid, is the major ingredient found in aspirin, which students will synthesize in the next experiment.

You will recall the effects of varying the length of the *R* group on the solubilities of alcohols, aldehydes, and ketones in water. Examine the chart on page 70 of the student module and discuss the solubility of the carboxylic acids in water as the *R* groups are lengthened. You may wish to mention that carboxylic acids are only one type of organic acid, and not all organic acids are weak. Another type of organic acid, the sulfonic acids (derivatives of sulfuric acid) are strong acids. Certain substituted carboxylic acids are also strong acids (trifluoroacetic acid, for example).

$$CH_3SO_3H + H_2O \longrightarrow CH_3SO_3^- + H_3O^+$$

methyl
sulfonic
acid

$$CF_3COOH + H_2O \longrightarrow CF_3COO^- + H_3O^+$$

trifluoracetic
acid

EXPERIMENT
O-40 SYNTHESIS OF ASPIRIN

The purpose of this experiment is to prepare a sample of aspirin and compare it with the commercial product.

Concepts

- Drugs are synthesized by chemical reactions.
- An impure product can be purified, and physical properties, such as solubility and melting point, can be used to help identify a compound or determine its purity.

Objectives

- Synthesize an aspirin sample.
- Observe and compare various properties of a laboratory sample with those of commercial aspirin.
- Do a melting-point determination.
- Use a handbook of physical constants to determine melting points.

Estimated Time Two laboratory periods

Student grouping Pairs

Materials

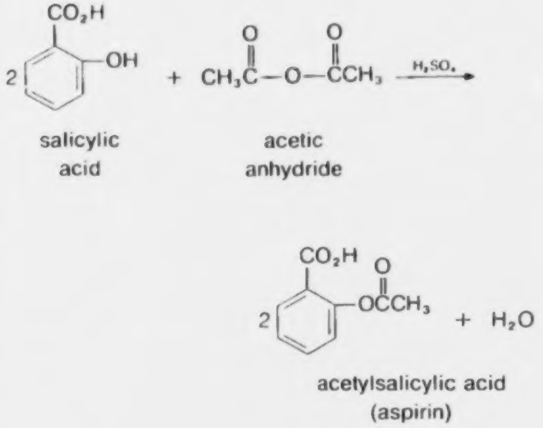
100 g salicylic acid
50 cm^3 acetic anhydride
150 cm^3 glacial acetic acid
25 cm^3 methyl alcohol (methanol)
5 cm^3 conc. sulfuric acid in dropper bottle
100 cm^3 0.5 M $NaHCO_3$ (4 g in 250 cm^3 H_2O)
250 cm^3 0.5 M HCl (dilute 10 cm^3 conc. HCl to 250 cm^3 total)
100 cm^3 0.1 M iron(III) chloride (1.6 g $FeCl_3$ in 100 cm^3 H_2O) in dropper bottle
50 cm^3 toluene
2000 cm^3 paraffin oil (mineral oil)
distilled water
ice
30 250-cm^3 beakers
15 400 *or* 600-cm^3 beakers (for ice bath)
15 250-cm^3 Erlenmeyer flasks
15 75-mm funnels
15 funnel supports
1 pkg. filter paper, 12.5-cm diameter
15 ring stands
15 4-inch rings
15 4-inch can lids (*or* Pyrex watch glasses)
15 wire gauze, plain (for supporting can lids)
15 Bunsen burners
15 wash bottles (plastic)
15 thermometers, $-10°C$ to $260°C$ *or* $-5°C$ to $400°C$
2 50-cm^3 burets
2 buret clamps
30 melting-point tubes (capillary), 9-cm lengths
litmus paper, red and blue
15 clamps, universal
15 glass stirring rods
15 rubber-tubing rings (for binding thermometer to melting capillary tube)
15 wire gauze, asbestos centers (for hot oil bath)

Advance Preparation Before presenting this experiment to your students, you may wish to synthesize aspirin yourself. If capillary tubing is not available, students can make their own by drawing out glass tubing over heat and cutting off 9-cm length pieces. Set up dispensing burets for acetic anhydride and glacial acetic acid. Also set up oil baths for the melting-point determinations.

Prelab Discussion Point out in discussion the reasons an organic chemist is interested in this sequence of laboratory activities: (1) synthesis, (2) purification, and

(3) identification. Discuss the fact that *all* of these steps are involved in this particular experiment.

The reaction for the preparation of aspirin is as follows:


salicylic acid

acetic anhydride

acetylsalicylic acid (aspirin)

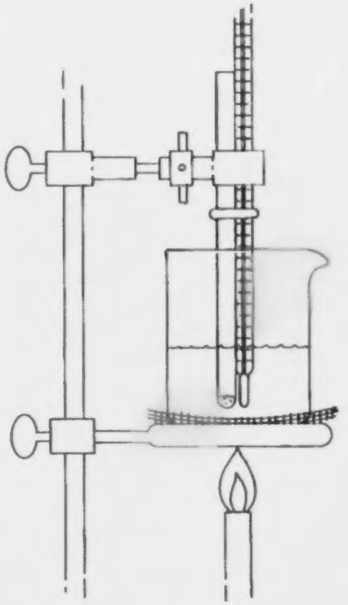
This is a slightly different reaction from the previous ones given for the preparation of esters. These involved an alcohol-containing compound and a carboxylic acid. Rather than treating the salicylic acid (which contains the alcohol group) with acetic acid to obtain aspirin, the anhydride* of acetic acid is used. The —OH group attached to a benzene ring is much less reactive in esterification reactions. Since acid anhydrides react much more readily with alcohols than do the corresponding acids, acetic anhydride is used instead of acetic acid to esterify salicylic acid.

Laboratory Tips Great care should be used in the handling of acetic anhydride and glacial acetic acid. Each of these reagents should be dispensed from 50-cm³ burets placed at central locations in the laboratory. Provide wastecans for reagent disposal.

Laboratory Safety Caution: *The students should wear goggles at all times. It is also extremely important that the room be well ventilated. Warn students that the final product is quite impure and should not be taken internally.*

Demonstrate the proper method and technique for determining melting points. You must use an oil bath—a water bath is not hot enough. **Caution:** *Be certain that no water gets into the oil bath.*

Demonstration *Melting Points:* A simple melting-point apparatus may be set up as shown in the following diagram. *Be certain that the rubber-tubing ring holding the thermometer and capillary tube together are not in the oil.* Better results may be obtained if students stir their oil baths occasionally.



The sample is inserted into the melting-point tube by taping the open end until about 2 mm of solid is inside the tube. Turn the tube over, and either carefully tap it with a finger or rub the open end with a file as shown in the following illustration. The vibrations should cause the sample to fall to the closed end of the tube.

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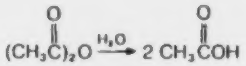
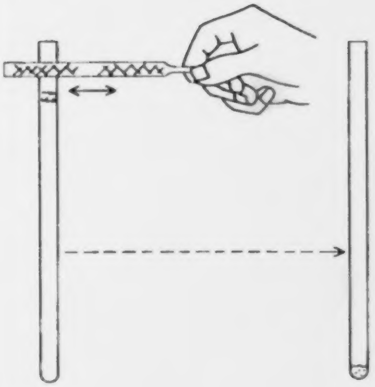
*Acid anhydrides when treated with water give the corresponding acid, thus showing the close relationship between these two types of compounds.



$$(CH_3\overset{\overset{O}{\|}}{C})_2O \xrightarrow{H_2O} 2\,CH_3\overset{\overset{O}{\|}}{C}OH$$

$$SO_3 \xrightarrow{H_2O} H_2SO_4 \qquad P_2O_5 \xrightarrow{H_2O} 2\,H_3PO_4$$



Give your students the approximate range of melting points of the starting reactants, or have them consult a chemistry handbook for this data.

Postlab Discussion Have students compare all samples of aspirin obtained in their laboratory syntheses. These results can be arranged in a chart comparing classroom synthesized aspirin with commerical aspirin.

Answer to Question #5: The purple color indicates the salicylic acid impurity present in the lab sample. This impurity is not found in the commerical sample.

O-41 SOAPS AND DETERGENTS

The margin illustrations on pages 72 and 73 and the photographs on page 74 of the student module will aid in your discussion of how soaps carry out their "cleaning" function. In the illustration on page 72, the wavy lines depict the hydrocarbon portion of the soap molecule that is able to dissolve in the nonpolar oil. The carboxylate end of the soap molecule, which is polar because of its ionic characteristics, is able to cling to the molecules of water. You may refer your students to *Diversity and Periodicity: An Inorganic Chemistry Module,* section *I-36,* which discusses the properties of water molecules.

Refer to page 73 of the student module, and discuss the chemical reaction of how sodium stearate, a soap, is made. The reaction takes place when fat and sodium hydroxide are mixed yielding sodium stearate and glycerol, $C_3H_5(OH)_3$. Fats are called triglycerides; glycerol is esterified with a fatty acid at each hydroxyl group. A given triglyceride may contain one to three different fatty acids in a variety of combinations.

Before students carry out their soap syntheses, discuss some common fatty acids (carboxylic acids) that are found in fats and oils.

$CH_3(CH_2)_{16}COOH$ stearic acid	$CH_3(CH_2)_{14}COOH$ palmitic acid
$CH_3(CH_2)_{10}COOH$ lauric acid	$CH_3(CH_2)_{12}COOH$ myristic acid

$CH_3(CH_2)_7CH{=}CH(CH_2)_7COOH$

oleic acid

$CH_3(CH_2)_4CH{=}CHCH_2CH{=}CH(CH_2)_7COOH$

linoleic acid

$CH_3CH_2CH{=}CHCH_2CH{=}CHCH_2CH{=}CH(CH_2)_7COOH$

linolenic acid

Analyses of hydrolyzed fats and oils for these acids show the following distribution:

Beef Fat: 29 percent palmitic acid, 20 percent stearic acid, and 42 percent oleic acid.

Butter: 12 percent myristic acid, 25 percent palmitic acid, 9 percent stearic acid, and 29 percent oleic acid.

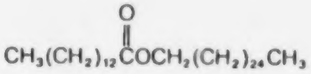
Cottonseed Oil: 29 percent oleic acid, 45 percent linoleic acid, and 21 percent palmitic acid.

Linseed Oil: 22 percent oleic acid, 17 percent linoleic acid, and 51 percent linolenic acid.

Soybean Oil: 8 percent palmitic acid, 28 percent oleic acid, and 54 percent linoleic acid.

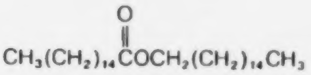
Those fats and oils that contain a number of unsaturated fatty acids spoil easily because of the reactive carbon-carbon double bonds. Linseed oil, which has a very high percentage of unsaturated fatty acids, is used as a base in paints. When exposed to the air, the oil "dries" and forms a tough, protective coat. This drying process is actually a polymerization of the oil which is initiated by a reaction with oxygen.

Another example of esters that are related to fats are the waxes. They are related to fats in that they are made up of esters of C_{12} to C_{20} fatty acids and C_{16} to C_{36} straight-chain alcohols. Discuss with your students how the fatty acids/alcohol chain composition affects the physical properties of waxes particularly with respect to solubility in water, boiling point, and melting point. Beeswax is rich in ceryl myristate and spermaceti. Wax that separates from whale oil and is used in candle making and in cosmetics consists mainly of cetyl palmitate.



$$CH_3(CH_2)_{12}\overset{O}{\overset{\|}{C}}OCH_2(CH_2)_{24}CH_3$$

ceryl myristate



$$CH_3(CH_2)_{14}\overset{O}{\overset{\|}{C}}OCH_2(CH_2)_{14}CH_3$$

cetyl palmitate

EXPERIMENT
O-42 PREPARATION OF SOAP

The purpose of this experiment is to prepare a soap and compare its properties to those of the commercial product.

Concepts

- Soap may be formed by a saponification reaction between sodium hydroxide and an oil or a fat.
- Soap acts as an emulsifying agent and aids in removing grease and dirt.

Objectives

- Demonstrate the preparation of a soap, beginning with an oil and sodium hydroxide.

Estimated Time One period

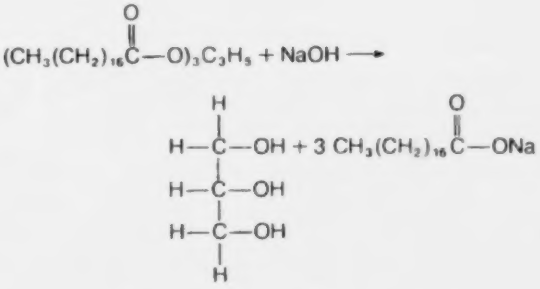
Student Grouping Pairs

Materials

100 cm^3 vegetable oil *or* animal fat
300 cm^3 denatured ethyl alcohol
250 cm^3 40 percent sodium hydroxide (40 g NaOH in 60 cm^3 H_2O)
750 g sodium chloride (NaCl)
distilled water
15 50-cm^3 graduated cylinders
15 250-cm^3 beakers
15 400-cm^3 beakers
15 Bunsen burners
15 18 x 150-mm test tubes
15 ring stands and rings
15 wire gauze, asbestos centers
15 glass stirring rods
paper towels, wet

Advance Preparation If you have never prepared soap in the laboratory before, you may wish to try this experiment before your students attempt it.

Prelab Discussion Review the chemistry of the following reaction and the laboratory procedure with your students:



$$(CH_3(CH_2)_{16}\overset{O}{\overset{\|}{C}}-O)_3C_3H_5 + NaOH \longrightarrow \begin{array}{c} H \\ | \\ H-C-OH \\ | \\ H-C-OH \\ | \\ H-C-OH \\ | \\ H \end{array} + 3\ CH_3(CH_2)_{16}\overset{O}{\overset{\|}{C}}-ONa$$

Laboratory Safety Reemphasize laboratory safety and urge your students to use caution when handling sodium hydroxide and ethanol. Advise students of the danger of alcohol fires, and require that they keep *wet* paper towels near their work areas to smother any flames that might occur. *Washing hands or face with the synthesized soap is not advised because of the excess base present in these laboratory soap samples.*

Postlab Discussion Have your students check their soap samples for solubility in water and in oil; have them determine its "sudsability" by shaking a sample with H_2O in a test tube.

Miniexperiment Ask students to bring samples of water from different sources to class (rainwater, tap water, lake water, etc., for testing). They will determine whether each sample of water is hard or soft. Discuss with your students how hard water affects the ability of soap-containing compounds to clean, including how hard water differs from soft water. Have them check on chemical reactions which may help illustrate or support the discussion.

Pollution of waterways by modern detergents containing phosphates and sulfonates contributes to eutrophication by providing nutrients that promote algae growth and metabolism. Discuss the pros and cons of the effects of this excess growth on other living systems present in the same water environment. For further reference, see *The Delicate Balance: An Environmental Chemistry Module.*

O-43 MAINTAINING THE CYCLE

Increased soap and detergent pollution has caused many environmental problems which you may wish to discuss with your students. Compare the structural formulas for dodecylbenzenesulfonate and the general formula for the biodegradable detergent found on page 76 of the student module. Point out to students how similar the molecular formulas of the compounds are, yet bacteria react only with the biodegradable compound and break it down. After comparing these two molecules, students will see that the nonbiodegradable molecule contains several branches in the carbon skeleton. It is for this reason that bacteria have trouble breaking down highly-branched molecules.

You may wish to make further comparisons of nonbiodegradable and biodegradable substances that have been involved in environmental issues and problems, some of which may have affected your community. Have students check the detergent boxes at home to see if any contain phosphates.

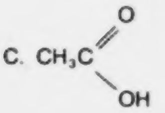
EVALUATION ITEMS

These are suggestions for evaluation items which you may wish to use with your students at various times during the preceding section. The correct answer to each question is indicated by shading.

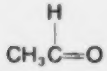
1. Draw and compare the oxidation states of the following functional groups: alcohols, aldehydes, ketones, acids.
2. The compound shown below that is classified as an acid is:

A. CH_3OCH_3

C.

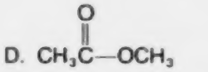


B.



$CH_3\overset{H}{\overset{|}{C}}{=}O$

D.



$CH_3\overset{O}{\overset{\|}{C}}{-}OCH_3$

3. Which of the following pairs of reactants could be used to prepare an ester?
   - A. ethyl alcohol, butyric acid
   - B. acetone, formaldehyde
   - C. formaldehyde, ethyl alcohol
   - D. both A and B
4. Describe how the molecular structures of soaps and detergents enable them to act as cleaning agents.
5. Soaps belong to which of the following classes of organic compounds?
   - A. esters
   - B. amines
   - C. aldehydes
   - D. salts of organic acids
6. Name a few of the advantages of detergents vs. soaps, with respect to their cleaning abilities in hard water and in soft water.
7. Discuss the environmental problems that result from the use of phosphate detergents and how these problems occur. What is being done to stop or minimize these problems?

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"Eliminating Phosphates in Detergents." *Chemistry*, January 1971, p. 3.

"Enzymes in Detergents." *Chemistry*, February 1970, pp. 25–26.

Gruchow, Nancy. "Detergents: Side Effects of the Washday Miracles." *Science*, 167:151 (1970).
Raises questions about the value of detergents as cleaning agents and their potential toxicity.

Hammond, A. L. "Phosphorus Replacements: Problems with the Washday Miracle." *Science*, April 23, 1971, p. 361.
Hornstein, Irwin, and Teranishi, Ray. "The Chemistry of Flavor." *Chemical and Engineering News*, April 3, 1967, pp. 92–108.
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Rukeyser, William S. "Fact and Foam in the Row Over Phosphates." *Fortune*, January 1972, pp. 70–73, 166–70.
Seyse, R. J., and Gordon, G. "Phosphates in Detergents." *Chemistry*, September 1972, p. 27.
Water Pollution—Causes and Cures. Manufacturing Chemists Association, 1977. (For a free copy, write to: 1825 Connecticut Avenue, N.W., Washington, DC 20009.)

SUGGESTED FILMS

The Manufacture of Soap. Color, 7 minutes. CCM Films, Inc., 34 MacQuesten Pkwy., Mt. Vernon, NY 10550.

Mechanisms of an Organic Reaction. Color, 20 minutes. A CHEM Study Film. Modern Learning Aids, Division of Ward's Natural Science Establishment, Rochester, NY 14603. A study of the hydrolysis of the methyl benzoate ester.

Organic Bases: The Amines

Nitrogen, the most abundant element in the atmosphere, is vital in the formation of the amines—organic compounds derived from ammonia. Discuss with your students some of the reactions characteristic of the amine functional group and the uses of these amines. Relate this to the chemical compounds suggested by the photograph on page 77 of the student module.

O-44 AMMONIA'S OFFSPRING

Compare the relationship of the alcohol and the ether functional groups to water; use this in your discussion of the relationship of ammonia to the amines. As both hydrogen atoms in water are replaced by *R* groups, so, too, are the hydrogen atoms of NH_3 replaced by *R* groups. The use of molecular models to build structural formulas of ammonia (student module page 78) and amines will help students to visualize these compounds. Discuss the importance of the compound NH_3, ammonia. Allow students to mix on a watch glass equal quantities of $Ca(OH)_2$ and NH_4Cl, noting the odor. Point out that amines and many other nitrogenous compounds are derivatives of ammonia.

$$Ca(OH)_2 + 2NH_4Cl \longrightarrow CaCl_2 + 2NH_3 + 2H_2O$$

The amines act as weak bases in a manner analogous to the action of the weak organic acids. However, there are virtually no strong amine bases; nearly all have K_b's $< 10^{-3}$.

$$RNH_2 + H_2O \rightleftharpoons R\overset{+}{N}H_3 + \overset{-}{O}H$$

Point out to your students the change in water solubility of the amines as the *R* group increases in length. The solubility characteristics of high molar-mass amines are used in the isolation of amine-containing natural products from other organic chemicals. By treating these compounds with dilute mineral acid (HCl or H_2SO_4), amines form water-soluble ammonium ions, NH_4^+, while other organic materials (hydrocarbons, alcohols, ketones, acids, esters) remain water insoluble. This is the key to the following demonstration.

Demonstration *Extraction of Amines from a Mixture:* The organic mixture containing amines is dissolved in an organic, water-insoluble solvent such as ether or chloroform. This solution is placed in a separatory funnel with dilute hydrochloric acid and shaken. Two layers form—an organic layer and an aqueous inorganic layer. The organic materials, except the amines, remain in the organic phase. This organic layer is washed several times with dilute acid to insure complete removal of the amines from the organic phase. If ether is used, the organic layer is the upper phase [$(H_2O > CH_3CH_2)_2O$ in density]. When using chloroform, the aqueous layer is the upper phase ($CHCl_3 > H_2O$ in density). The amines can be recovered from the aqueous layer by adding a base and extracting the insoluble amines into ether or chloroform.

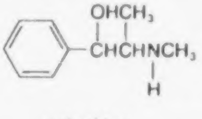
Examination of the nitrogen atom in ammonia (structural formula page 78) shows why amines have the ability to act as bases—to bond with a hydrogen ion. The unshared pairs of electrons located on the nitrogen atom in both the ammonia and the amine functional groups attract a positively charged ion such as hydrogen, thus meeting the requirement to act as a base. The equation on page 78 of the student module illustrates this general base reaction.

Discuss the classifying of amines as primary, secondary, and tertiary as you did in the discussion of alcohols. Have students identify the type of amine that the structures on page 78 of the student module represent. Compare the different properties of the primary, secondary, and tertiary compounds.

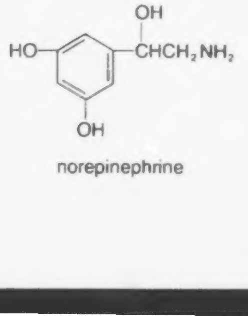
The unshared pair of electrons on the nitrogen atom also gives it the capacity to bond with a fourth atom or group of atoms—one more than nitrogen usually bonds to—to form an ammonium salt. The reaction of a water-insoluble amine and hydrochloric acid to produce a water-soluble salt is shown on page 79 of the student module. The charged end of the salt compound can now interact with polar molecules and dissolve. The presence of a long hydrocarbon chain with an ionized end resembles detergents and soaps, as studied in section *O-41*. Discuss why the term "invert soap" is used by comparing the structural formulas (page 79 of the student module) with the soaps made from the combination of carboxylic acids and an inorganic base, such as sodium hydroxide.

The amine group is perhaps not as widely known as other organic compounds, but, nevertheless, they hold important roles in chemical technology, medicine, and in the structures of living organisms.

Ephedrine is used to relieve the symptoms of colds, hay fever, and asthma. Norepinephrine contracts the capillaries in the mucous membranes of the respiratory system and elevates blood pressure. Norepinephrine is an isomer of epinephrine, also known as adrenaline.

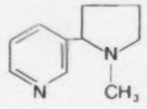


ephedrine



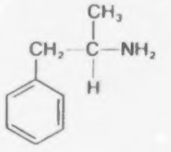
norepinephrine

Nicotine, a well-publicized amine because of its presence in tobacco, is used as an insecticide. It is also known to affect the blood pressure and the central nervous system of humans.



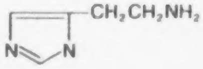
nicotine

Amphetamine (trade name benzedrine) is an amine which finds wide medical applications because it reduces respiratory congestion caused by colds, hay fever, and asthma. It stimulates the central nervous system, increases blood pressure, and is used in sleep-suppressants and diet pills (because of its appetite-reducing effects). However, it may have side effects and can be habit forming.



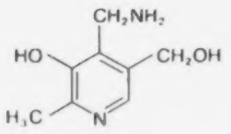
amphetamine

Allergic reactions are associated with histamines present in body tissues. Normally, histamine is considered inactive in its bound form. It is converted to a free, active form by the presence of various stimulants introduced into the body. Allergic responses such as hives, hay fever, and asthma may result. The ability of histamines to dilate blood vessels and stimulate gastric juice secretion has important medical and biological uses.

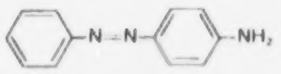


histamine

Aniline (structural formula on page 78 of the student module) is used as a raw material in the preparation of many dyes. Other amines are pyridoxamine (a vitamin B complex), *p*-aminoazobenzene (a yellow dye), and 1,6-hexanediamine (an ingredient used in the production of nylon polymers).



pyridoxamine



p-aminoazobenzene

$H_2N—CH_2CH_2CH_2CH_2CH_2CH_2—NH_2$

1,6-hexanediamine

Amines form cyclic compounds of special importance to living organisms such as the nucleic acids adenine, guanine, cytosine, thymine, and uracil. You may wish to discuss with your students the biological significance of DNA and RNA. You may also wish to refer to *Molecules in Living Systems: A Biochemistry Module* for molecular structures and further references on these topics.

O-45 MOLECULAR NITROGEN

Where does pure oxygen come from? In what compounds is it found? Once oxygen combines with other elements, is this oxygen bound forever? Why doesn't the earth's atmosphere ever run out of oxygen which is required by so many organisms to stay alive? The element oxygen exists in compound form with other elements and in the molecular form O_2. By natural processes, oxygen is recycled so that it is present in more than one form.

Nitrogen is a relatively stable, unreactive element when compared with oxygen. Discuss the ways that nitrogen gas, N_2, may combine with other elements in chemical reactions to lead to the formation of more complex nitrogen-containing compounds. Oxidation by electrical storms to form nitrates and nitrites (NO_3^- and NO_2^-, respectively) is one method. Another way is carried out by organisms in the soil and in root nodules of leguminous plants. Certain microorganisms reduce nitrogen to ammonia ($N_2 \longrightarrow NH_3$). The nitrifying bacteria oxidize the ammonia to form NO_2 and NO_3.

Plants either absorb ammonia directly before it is nitrified to help form plant tissues, or they may absorb the nitrites and the nitrates. Once inside plant tissues, these nitrogen compounds are recombined with other organic compounds to help form proteins and nucleic acids which are fundamental to plant growth. Animals and humans obtain nitrogen by consuming plant and animal tissues. Microorganisms also require nitrogen in their metabolism and may obtain this from once-living tissue in the process known as decay.

The natural production of ammonia from molecular nitrogen (N_2) and molecular hydrogen (H_2) can be looked upon as a great biological feat because nitrogen is not that reactive. Compare nature's way to the technology known as the Haber process (page 82 of the student module), which requires a large amount of heat energy. (Also see *Diversity and Periodicity: An Inorganic Chemistry Module* for further discussion.) Developed prior to World War I, the Haber process enabled Germany to produce ammonia on a large scale. Ammonia was converted to nitrates which were necessary for the production of explosives and munitions. In addition to aiding in the production of munitions, the Haber process and modifications of it have been instrumental in promoting successful agricultural efforts throughout the world. From the raw material of ammonia, which itself may be used as a fertilizer, nitrates as well as urea are produced for use as plant nutrients. Discuss the chemical reactions shown on page 82 of the student module illustrating the formation of urea from ammonia and carbon dioxide.

Discuss the significance of the synthesis of ammonia as an example of human control over the environment. You may wish to have your students research the chemical compositions of various plant foods and fertilizer containers and the importance of each nutrient to plant growth. Some students who are interested in growing vegetables may check to find out which fertilizers would be best for different types of plants such as root crops, leafy crops, and stem crops. Discuss the economic, social, and political impact of mechanized, mass-production farming on your local community, the country, and the world.

What are the advantages of using concentrated fertilizers and the "organic" method? Discuss examples of the problems and the residual effects of the overuse of fertilizers on the soil.

Urea is an organic compound excreted by living organisms as a final breakdown of proteins in the metabolic process. Birds and reptiles excrete uric acid, and most aquatic animals excrete ammonia. Refer to the structural formulas of these excretory products on page 82 of the student module.

The carbon cycle is equally as complex, essential, and intriguing as the nitrogen cycle. It may be studied in some detail in conjunction with a review of glycolysis and photosynthesis (see *Molecules in Living Systems: A Biochemistry Module*).

Although carbon exists as a pure element in some inert forms, such as diamond and graphite, it is also found in the form of CO_2, carbon dioxide gas. Discuss the variety of ways that CO_2 is formed including the burning of fossil fuels and the excretion of CO_2 by living organisms. Although not a readily usable form of carbon by most living systems, carbon dioxide is combined with hydrogen to form glucose, a carbohydrate, by the process of photosynthesis in green plants. This carbon incorporated into glucose molecules is available to nonphotosynthetic organisms for use in their metabolic processes.

The idea of recycling chemical elements to form complex molecules and their resultant breakdown to simpler molecules is fundamental to life on this planet. Discuss with your students the importance of the cycles as illustrated on page 81 of the student module. Relate the concepts of recycling and biodegradation of the chemical elements to detergents in sections *O-42* and *O-43*. You may wish to discuss the hypothetical occurrences of increasing quantities of carbon and/or nitrogen that may become bound in nondegradable pollutants, thus preventing the continuation of these cycles.

EVALUATION ITEMS

These are suggestions for evaluation items which you may wish to use with your students at various times during the preceding section. The correct answer to each question is indicated by shading.

1. Describe how ammonia is related to trimethylamine.
2. Write the formula for an "ammonium salt" of an amine.
3. Describe the similarities and differences between an "invert" soap and "regular" soap.
4. Define what is meant by a base (as opposed to an acid), and discuss the characteristic properties of the amine functional group that make this group basic.
5. Discuss the nitrogen and the carbon cycles and their significance to the living chemical world.
6. In general, what is the main reason for chemical recycling? Why is it essential that this process not be interrupted?
7. Discuss the impact that the Haber process has had on the history of agricultural technology.
8. From the excretory products of various animals, how is the nitrogen cycle continued?
9. Write a general equation showing how an organic amine can act as a base. Use *R* for the nonfunctional group portion of the molecule.
10. Bacteria convert molecular N_2 into which of the following:

    [✓ A.] NH_3 C. NO_2
    B. NO_3 D. amino acids

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Janick, Jules; Noller, Carl H.; and Rhykerd, Charles L. "The Cycles of Plant and Animal Nutrition." *Scientific American*, September 1976, p. 74.
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Safrany, D. R. "Nitrogen Fixation." *Scientific American*, 231(4), p. 64 (1974).

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Simpson, C. H. *Chemicals from the Atmosphere*, 1973. Dept. SIS, American Chemical Society, 1155 16th Street, N.W., Washington, DC 20036.

Skinner, K. J. "Nitrogen Fixation." *Chemical and Engineering News*, October 4, 1976.

SUGGESTED FILMS

The Great Difference. Color, 28 minutes. Motion Picture Bureau, 1416 Dodge St., Omaha, NE 68102.
The combined efforts of agriculture and industry work to develop and apply fertilizers which improve both the quality and the quantity of food.

Nitrate, Nitrogen Story. Ortho Division, California Chemical Corp.

Nitrogen and Ammonia. Color, 16 minutes. Coronet Instructional Films, 65 E. South Water St., Chicago, IL 60601.

The Nitrogen Cycle. Black and white, 14 minutes. Universal Education and Visual Arts, 100 Universal City Plaza, Universal City, CA 91608.

Polymers: The Linking of Molecules

Almost everyone finds it difficult to visualize a molecule—to develop a concept of an object which is invisible and which cannot be brought into view even with the aid of a microscope. Having first learned about molecules in the primary grades, your students will have some notion of what a molecule is and its importance to chemistry. At this time, though, you are asking students to go a step further and to recognize size differences among invisible molecules. You may find it helpful to refer to structural formulas of molecules as a means of developing a concept of macromolecules. It is important at the outset that students understand the meaning of *macromolecules*.

In presenting this section to your students make use of the illustrations and photographs provided in the text. Suggest that your students add to these by preparing charts, displays, and samples from sources that are available to them. Encourage students to collect and bring in articles from periodicals and newspapers and lists of names and formulas of polymers that are present in and around their environment. Help them relate these to the sections that are being discussed.

Some of the history of polymer research and development is quite fascinating. Encourage members of your class to research this information and relate it to their classmates. Whatever methods you use, your students will, no doubt, find this section interesting as it affects each of them in their everyday lives.

O-46 THE MAKING OF MACROMOLECULES

The term polymer describes the kind of giant molecules from which plastics are made. *Polymer* comes from the Greek meaning "made up of many" *(poly)* "parts" *(mer)*. Also from the Greek is *isomer* meaning "made from the same" *(iso)* "parts" *(mer)*. Polymers are made by stringing together many identical small molecular units called *monomers* (*mono* meaning "one" or "single").

A polymer contains thousands of atoms. Rubber, a naturally occurring polymer, may have a molecular mass of almost one million. Therefore, a mole of rubber weighs 1000 kilograms, or about 1 ton. With molecules of this size, it can be expected that the properties of a substance composed of polymers depend on what the chains are made of and how they are arranged. Apply what has been previously studied concerning chains of carbon atoms to predict that some polymer chains can be branched. You can also conceive of branched chains hooking together to form cross-linkages among chains. This occurs in some polymers with structures resembling giant nets or tangles in two or three dimensions, as will be discussed in the next section.

Miniexperiment Have students make a list of items that they think are made from polymers and are used everyday either in the home or in the classroom. Have them try to identify a few of the kinds of polymers used in making these items.

Review with students how to write formulas for monomers and polymers. Give a simple formula for a monomer and then its polymer, and ask students to calculate the mass of the monomer and then the mass of the corresponding polymer.

O-47 FROM MONOMER TO POLYMER

Review the examples on pages 86 and 87 in the student module, and then you may wish to give your students more practice examples of the building of polymers and copolymers through combinations of monomeric units. Discuss the variety of monomers available, and, as an example, you can use the twenty naturally-occurring amino acids to reinforce the idea of nature's molecules that are also polymers. You may also wish to refer to *Molecules in Living Systems: A Biochemistry Module*.

EXPERIMENT
O-48 SYNTHESIS OF NYLON 66

The purpose of this experiment is to illustrate the preparation of the synthetic polymer nylon 66.

Concepts

- Polymers are formed by joining together many small molecules called monomers.
- Polymers are molecules that have large molecular masses.

Objectives

- Demonstrate that ordering (stretching) a polymer increases its strength.
- Synthesize a simple polymer such as nylon 66.

Estimated Time One period

Student Grouping Pairs

Materials

100 cm^3 0.5 M hexamethylenediamine solution
100 cm^3 0.25 M adipyl chloride solution
50–100 cm^3 acetone *or* ethanol
15 10-cm^3 graduated cylinders
15 15-cm lengths of copper wire *or* paper clips
15 50-cm^3 beakers

Advance Preparation You may wish to pretest this experiment before presenting it to your class. Prepare the adipyl chloride and hexamethylenediamine solutions as follows:

Adipyl chloride: Dissolve 4.6 g adipyl chloride in 100 cm^3 of petroleum ether (60–80°C boiling fraction). This can be used in place of the hexane called for in the student module.

Hexamethylenediamine: Prepare 100 cm^3 0.5 M NaOH by dissolving 2 g NaOH in 100 cm^3 H_2O. Add 5.8 g of hexamethylenediamine to the 0.5 M NaOH solution.

Place the solutions in stoppered bottles. For easy access, distribute them to central locations throughout the laboratory.

Prelab Discussion A discussion of polymers—their structures and their properties—may be useful to your students. Household plastics and other polymers can be brought to class and treated with various reagents such as 6 M HCl, H_2SO_4, NaOH, and acetone as well as dyes (RIT) as a demonstration of plastics and their properties. Some polymers will dissolve, some will take a dye, while others will have no reaction. It depends on the properties of each polymer.

Laboratory Tips This experiment should be carried out using small beakers (50 cm^3). Students should roll the nylon on an 18 x 150-mm test tube for best results. Provide waste disposal jars throughout the laboratory for excess solutions.

Postlab Discussion A further discussion of polymer properties *vs.* structure could be utilized here. Discuss the role of sodium hydroxide in the experiment. The reaction of the acid chloride and amine produces HCl as a by-product. The HCl formed tends to react with the diamine (a base) to form a salt which is unreactive in the polymerization reaction. The role of the NaOH is to neutralize the HCl.

The following questions may be used in evaluating your students' understanding of this experiment:

1. Starting with the formula for vinyl chloride, illustrate how the polymer polyvinyl chloride could be made. Use structural formulas only.
2. What is the role of NaOH in the preparation of nylon 66?
3. What unique properties does a molecule with two different functional groups possess? Give an example.
4. List some naturally occurring polymers and their uses.
5. List some synthetic polymers and their uses.
6. What properties of a solvent are important for polymer reaction?
7. Suggest reasons why your synthesized polymer does not closely resemble normal nylon.

Point out to your students that the reaction of an acid chloride (adipyl chloride) with an amine (hexamethylenediamine) will take place regardless of the solvent. A polymer will be obtained in the form of a white solid and not in the convenient fiber form as was found in the synthesis of nylon 66. You might suggest that your students try (or you may wish to demonstrate) mixing the two solutions (adipyl chloride and hexamethylenediamine) by stirring rapidly. The physical appearance of the polymer will be quite different from the "rope" described in this experiment *(O-48)*.

O-49 PROPERTIES OF POLYMERS

There are several ways that long-chain molecules can be arranged so that materials made from monomer units will have different properties. Two classroom demonstrations are described here to help your students understand molecular chains and polymers.

The simplest form of polymers is a completely random coiling of the chains, such as those found in cooked spaghetti, string, rubber bands, or a can of worms. Using spaghetti to show how ordering increases the strength of a polymer, try the following as a classroom demonstration.

Demonstrations: Cook spaghetti with a little oil or margarine so that the strands are slightly greased and will slide against each other.

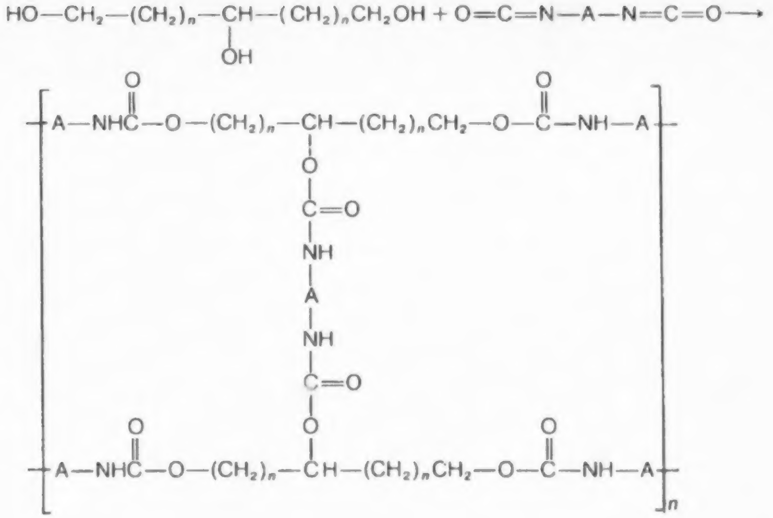
Dump the spaghetti onto a table top. Indicate to your students that each strand is to represent a polymer molecule. Grab two handfuls of the spaghetti and lift them up in front of you. Note that the strands are tangles, mixed up, and that there are few linkages between your hands. That is, not many of the molecules tend to hold or interconnect the two masses. This is an example of a "disordered" or "weak" fiber. Take the same spaghetti and lay it on the lab bench. "Comb" the strands, using your fingers. Now pick up the "ordered" fiber in both hands—the fiber is now obviously much stronger. There are many more connections between your hands.

Now hold the spaghetti in one hand. Some of the strands will fall out. Others will be so long that their other ends could not possibly be held by your hand. You can demonstrate this by taking some of the long strands and pulling them from the fiber. These strands were held in the fiber by the other polymer molecules. You can conclude by relating this to the hydrogen bonding in nylon which keeps the individual polymer molecules together.

This arrangement of polymer chains is used widely in the manufacture of plastic bags and wrappings. They are flexible but can be torn rather easily.

Use a scouring pad or "Tuffy" to demonstrate the second type of polymer—a cross-linked polymer. The polymer has considerable strength, yet it remains flexible. The more cross-linking in three dimensions, the stiffer the polymer will be. This type of molecular arrangement is used in making materials for telephones, radio and television cabinets, and urethane foam.

CROSS-LINKED POLYMER

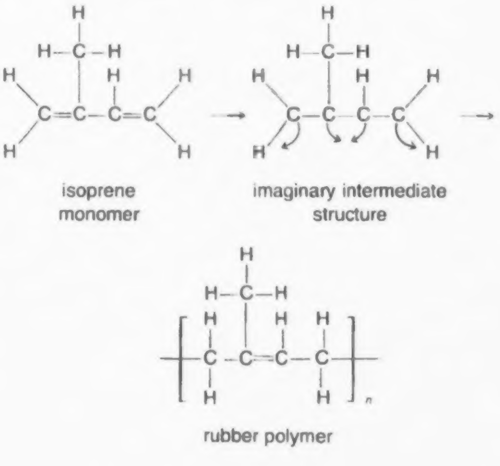


Polymers have many characteristic properties, but two of the most important ones are the ability of polymers to return to their original shapes (their memory) and a high viscosity or resistance to flow. The ability of polymers to return to their original shapes is due to the cross-linking which results from the entanglement and the chemical bonding between chains. Many polymers, known as *elastomers*, can be stretched over ten times their normal lengths and will return to their original dimensions thousands of times. Only polymeric materials have the ability to do this.

The high viscosity in a long polymer chain is due to the arrangement of the planes—a friction or drag, often results between planes which opposes free flow. A final characteristic property of polymers is their poor solubility. This is a result of the inability of solvent molecules to penetrate the interior of the polymer. According to the physical properties, polymers are classified as fibers, elastomers, or plastics. These categories may vary, however, if they are combined with other polymers. Rubber, one polymer made by nature, was discovered by the natives of Central America in the sticky fluid they found oozing from broken places in the barks of various trees. This fluid, known as latex, is an emulsion of rubber particles in water. The name rubber came to be used in the late 18th century by people who found that this substance could be used to rub out pencil marks.

Rubber, heated in the absence of air, forms a hydrocarbon molecule, C_5H_8, called isoprene, which distills out of the rubber. At ordinary temperatures, isoprene is a liquid that reverts to a rubberlike solid on standing. Isoprene has been identified as the monomer from which nature makes the polymer rubber.

Rubber is formed from the polymerization reaction of isoprene as follows:



The intermediate structure is drawn to suggest how the two C=C bonds in the isoprene molecule change position to form the polymer rubber. Note that one of the C=C bonds of isoprene is used to string the polymer together. Another important aspect of this double bond is that this is the spot where the chemical action occurs during the process known as vulcanization. Raw rubber is a very sticky compound that pulls apart without being very elastic; it has none of the strength or resilience common to rubber bands. Mixed and heated with sulfur, however, rubber makes a much stronger material due to the cross-links that are formed between the chains. Compare the structures of natural rubber *(cis)* and *gutta percha (trans)* stressing that minor differences in structure will result in major differences in properties. Examine the table of synthetic rubber compounds on page 91 of the student module. You may wish to have students research this topic and read about the chemist, Charles Goodyear, who discovered the vulcanization process. The ability of chemists to synthesize modified polymers allows for the tailoring of a specific polymer for a specific function.

O-50 NATURAL AND SYNTHETIC POLYMERS

On the chalkboard, write the empirical formulas for two natural polymers—starch and cellulose. The formula for starch is the same as the formula for cellulose, another polymer of glucose. Discuss the fact that humans can digest starch but not cellulose. As the student module points out, the human body has neither the enzyme nor the bacterium which produces the enzyme needed to digest cellulose and convert it to glucose for energy.

The development of synthetic polymers has increased the varieties of plastics, rubber substitutes, and synthetic fibers, although there is no sharp line that can be used in separating these polymers from each other. For example, the same basic material that is used to make nylon can be molded to make "plastic" toys or spun into fibers and woven into cloth. The differences lie in the arrangement of the molecules that form the basic material.

Discuss with your students the increased use and production of synthetic polymers. You may wish to have your students research the history of polymers (or a specific polymer) and the impact they have on today's living. In discussing the photos on page 95 of the student module, you may wish to ask your students to find other photos in newspaper or magazine articles that illustrate polymers and their uses. Besides being used in the manufacturing of clothing and household appliances, polymers have many wide-ranging uses in medicine, space travel, industrial products, and recreational items. Have students make a list of the common items they use everyday that are polymers or derivatives of polymers.

There are two major types of polymerization reactions: addition and condensation reactions. In an addition polymerization reaction, a reactive species (usually a radical or an ion) adds to a molecule (most often an alkene) to give a new reactive species, which, in turn, reacts with another molecule as illustrated in the following equation:

$$CH_3CH_2\cdot + CH_2{=}CH_2 \longrightarrow$$

$$CH_3CH_2{-}CH_2CH_2\cdot \xrightarrow{CH_2=CH_2}$$

$$CH_3CH_2{-}CH_2CH_2{-}CH_2CH_2\cdot$$

However, in a condensation polymerization reaction, the reactive molecules must have two or more functional groups. When the molecules react, not only is a polymer chain started, but at each step an additional small molecule, such as water, is produced. As was evidenced in the synthesis of nylon 66, the small molecule split out is HCl.

The polymerization of glucose yielding starch or cellulose and the polymerization of amino acids yielding proteins are condensation polymerization reactions. The polymer shown on page 94 of the student module is an example of a condensation polymer.

EXPERIMENT
O-51 MIRROR IMAGE MOLECULAR MODELS

This activity will give students some first-hand experience in constructing models and interpreting mirror image isomerism.

Concepts

- Mirror image isomerism is associated with asymmetric C atoms.
- The two images of a mirror isomer can be likened to a right and a left hand.

Objectives

- Make models of compounds that have mirror images (asymetric carbon atoms).
- Make distinctions among geometric, structural, and mirror-image isomers, and give an example of each.

Estimated Time One laboratory period

Student Grouping Pairs

Materials

15 molecular model kits (colored Styrofoam balls and toothpicks, stale marshmallows *or* clay can also be used)

Advance Preparation None

Prelab Discussion Review the rules for carbon bonding.

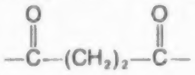
Postlab Discussion Review structural and geometric isomerism relating these to mirror image isomerism. The tetrahedral arrangement of atoms may be hard for students to envision at first, but with the aid of a model with four toothpicks as far apart as possible, this should not be too difficult.

EVALUATION ITEMS

These are additional items that you may wish to use with your students at various times during the preceding section. The correct answer to each question is indicated by shading.

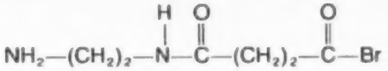
1. A polymer has the structure $\left[A-B \right]_n$

If A is $-NH-(CH_2)_2-NH$ and B is

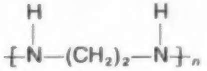


$-\overset{O}{\overset{\|}{C}}-(CH_2)_2-\overset{O}{\overset{\|}{C}}-$

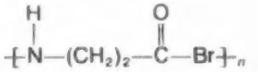
the repeating unit of the copolymer is:

A. 

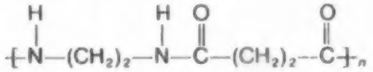
$NH_2-(CH_2)_2-\overset{H}{\overset{|}{N}}-\overset{O}{\overset{\|}{C}}-(CH_2)_2-\overset{O}{\overset{\|}{C}}-Br$

B. 

$\left[\overset{H}{\overset{|}{N}}-(CH_2)_2-\overset{H}{\overset{|}{N}} \right]_n$

C. 

$\left[\overset{H}{\overset{|}{N}}-(CH_2)_2-\overset{O}{\overset{\|}{C}}-Br \right]_n$

D. 

$\left[\overset{H}{\overset{|}{N}}-(CH_2)_2-\overset{H}{\overset{|}{N}}-\overset{O}{\overset{\|}{C}}-(CH_2)_2-\overset{O}{\overset{\|}{C}} \right]_n$

2. A polymer is made from monomers B and C as follows:

$B + C \longrightarrow BC$
$BC + B \longrightarrow BCB$
$BCB + C \longrightarrow BCBC$

The polymer has the formula $B-(C-B)_6-C$.

If the weight of B = 25 and the weight of C = 50, the weight of the polymer is:

A. 525
B. 500
C. 475
D. 225

3. Discuss how the molecular structure of a monomer affects the properties of a resultant polymer.

4. Shower curtains and lightweight furniture are both made from plastic compounds. Explain in terms of how the polymer chains are linked together why one is flexible and the other is not.

5. Explain the process of vulcanization and how it makes rubber stronger and more elastic.

6. Discuss the future of the plastics industry and the effects it will have on one's daily life.

SUGGESTED READINGS

Carraher, Charles E., Jr. "What Are Polymers?" *Chemistry*, June 1978, pp. 6–10.
Debye, P. J. W. "How Giant Molecules Are Measured." *Scientific American*, September 1957, pp. 90–97.

Ferris, James P. "Biopolymers and the Origin of Life." *Chemistry*, June 1978, pp. 14–16.

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Kauffman, George B. "Left-handed and Right-handed Molecules: Louis Pasteur's Resolution of Racemic Acid." *Chemistry*, April 1977, p. 44.
This is the story of Pasteur's studies of optical isomers in racemic acid.

Kaufman, Morris. *Giant Molecules*. Garden City, NY: Doubleday & Company, 1968.
Excellent photographs.

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Leuchtag, H. R. "Polymer Additives Reduce Fluid Drag in Turbulent Flow." *Physics Today*, March 1978, pp. 17–19.

Man-Made Fiber Fact Book. Man-Made Fiber Producers Association, Inc., Education Department, 1150 17th Street, N. W., Washington, DC 20036. 1974.

Mark, Herman F. "Polymers for the Future." *Chemistry*, June 1978, pp. 28–30.

Meloan, Clifton E. "Fibers—Natural and Synthetic." *Chemistry*, April 1978, pp. 9–12.

Morton, M. "Big Molecules." *Chemistry*, January 1964, pp. 12–17. Reprint No. 42.

———. Design and Formation of Long Chain Polymers." *Chemistry*, March 1964, pp. 6–11. Reprint No. 43.

———. "Polymers—Ten Years Later." *Chemistry*, October 1974, p. 11.

Natta, G. "Precisely Constructed Polymers." *Scientific American*, August 1961, p. 33. Offprint No. 315.

Nelson, Gordon L. "Fire and Polymers." *Chemistry*, June 1978, pp. 22–27.

"Polymeric Food Additives." *Chemistry*, June 1977, p. 23.

"Polyurethanes." *Chemistry*, October 1975, pp. 20–21.

Sears, Jerry. "Polymer Pioneers." *Chemistry*, September 1977, pp. 6–10.

Shalaby, Shalaby W., and Pearce, Eli M. "The Role of Polymers in Medicine and Surgery." *Chemistry*, June 1978, pp. 17–21.

Taking Things Apart and Putting Things Together. American *Chemical Society*, 1155 16th Street, N.W., Washington, DC 20036. pp. 64–69. 1976.
History and discussion of some of the significant polymers known today and the groundwork that went into their development.

"Teflon—From Nonstick Frying Pans to Space Vehicles." *Chemistry*, June 1965, pp. 21–22.

Tonelli, Alan E. "Sizes and Shapes of Giant Molecules." *Chemistry*, June 1978, pp. 11–13.

SUGGESTED FILMS AND FILMSTRIPS

Films:

Fibers and Films. Color, 20 minutes. Product Information, FMC Corp., Fiber Division, 1185 Ave. of the Americas, New York, NY 10036.
Shows the manufacture of rayon, acetate and cellophane and a panoramic view of the many diverse uses of these synthetics.

Magic Touch. Color, 22 minutes. Goodyear Tire & Rubber Co., Public Relations Film Library, 1144 E. Market St., Akron, OH 44316.
A chemistry-oriented treatment of the synthesis of latex including discussions of lattice structure, the use of catalysts to assist reactions, and the influence of molecule characteristics on the properties of the finished product.

Nothing to Chance. 15 minutes. Ren Plastics, Inc., Advertising Dept., 5656 South Cedar St., Lansing, MI 48909.
Emphasizes that in the formulation of plastics, chemists must study and understand the properties of the raw materials in order to produce a new substance with specifically desired characteristics.

Our Polymer World. Color, 22 minutes. Polysar Inc., 1795 W. Market St., Akron, OH 44313.

Physical Chemistry of Polymers. Color, 22 minutes. American Telephone and Telegraph Co., Information Dept., 195 Broadway, New York, NY 10007.

The Poetry of Polymers. Color, 19 minutes. National Audiovisual Center, General Services Administration, Washington, DC 20409.
Actual research in polymers shown; emphasizes the need to understand the basic chemical nature of materials.

A Stretch of the Imagination. Color, 25 minutes. Bureau of Mines, U.S. Dept. of the Interior, Motion Pictures, 4800 Forbes Ave., Pittsburgh, PA 15213.
Story of industry's search for synthetic rubber.

A Stretch of the Imagination. Color, 20 minutes. Goodyear Tire & Rubber Co., Public Relations Film Library, 1144 E. Market St., Akron, OH 44316.
Compares two very different types of synthetic rubber.

The Wonderful World of Nylon. Color, 13½ minutes. Motion Picture Section, Advertising Dept., E. I. du Pont de Nemours & Co., Inc., Wilmington, Delaware 19898.
Discusses nylon and other fibers modeled after it.

Filmstrips:

Rayon Today. Sound filmstrip. Product Information, FMC Corp., Fiber Division, 1185 Ave. of the Americas, New York, NY 10036.

Shapes and Structures in Nature. 4-filmstrip set. BFA Education Media, Division of CBS Inc., 2211 Michigan Ave., P. O. Box 1795, Santa Monica, CA 90406.
Relates atomic and molecular structure to the properties of natural and man-made materials.

BEST COPY AVAILABLE

Photochemistry: Light and Heat

Review with your students their understanding of light and heat. Use the photograph of the solar flare on page 98 of the student module, and discuss the chemical reactions on the sun which result in light and heat energy for the earth. Refer to *The Heart of Matter: A Nuclear Chemistry Module* for further information on this topic.

O-52 COLD LIGHT: ITS SOURCES

During discussion of this section, stress the terms luminescence, bioluminescence, and chemiluminescence. Point out that the prefix indicates the source of the light. Another type of luminescence is photoluminescence. Certain substances, when irradiated with light—visible or invisible—in turn release their own light energy. This phenomenon is evident when certain minerals are radiated with ultraviolet light. Upon absorbing the ultraviolet light, they release energy through phosphorescence or fluorescence. Both are examples of photoluminescence.

One of the best examples of light emitted by a living organism is the firefly. Discuss the chemical reaction that appears on page 99 of the student module in which luciferin is oxidized and the firefly produces cold light. The reasons why the firefly produces light are quite fascinating and might provide an interesting research topic for some students. Further information on this chemical process and the firefly can be found in sections *B-33* and *B-34* of *Molecules in Living Systems: A Biochemistry Module.*

Proceed with a discussion of experiment *O-53* where students will demonstrate the emission of cold light using luminol, one of the few chemicals that undergoes such a reaction.

EXPERIMENT
O-53 CHEMILUMINESCENCE OF LUMINOL

This experiment will acquaint students with the phenomenon of chemiluminescence and show them that no heat is emitted in this type of reaction.

Concept

- Some reactions give off energy as light without accompanying heat.

Objectives

- Describe energy release in terms of heat and light emission.
- Demonstrate the phenomenon of chemiluminescence in the laboratory using appropriate chemicals.
- Identify the catalyst which best produces chemiluminescence in the luminol reaction.
- Observe the effects of an acid and a base on the luminol reaction.

Estimated Time One period

Student Grouping Pairs

Materials

15 0.2-g luminol samples
200 cm^3 2.5 M NaOH solution
300 cm^3 3 percent H_2O_2
2 dropper bottles 40 percent NaOH
2 dropper bottles conc. HCl
10 g copper(II) sulfate
10 g chromium(III) chloride
10 g potassium chloride
10 g potassium iron(III) cyanide
10 g magnesium sulfate
75 13 x 100-mm test tubes
15 test-tube racks
15 corks for test tubes
15 spatulas
15 250-cm^3 Erlenmeyer flasks
15 500-cm^3 Erlenmeyer flasks

Advance Preparation Test the experiment before the class attempts it. Prepare 0.2 g luminol samples in vials or test tubes for distribution to the students.

The 2.5 M NaOH solution should be prepared by adding 20 g NaOH to 200 cm^3 of water. The 40 percent NaOH solution should be prepared by adding 40 g NaOH to 60 cm^3 of water.

Prelab Discussion The nature of energy release in various forms from a chemical reaction should be discussed. Compare burning, explosions, and cold light in terms of the forms of energy that are evident when these chemical reactions occur. The production of light without the concurrent formation of excessive heat or force is of importance to the survival of many living things because they cannot withstand the heat of any other type of light-producing reaction. This experiment is a model for cold-light chemical reactions which occur in living systems.

Laboratory Tips It is very important that the area be darkened as much as possible, and that the test tube with the reactants should be observed in a black box or against a dark background such as a sink.

Postlab Discussion The students should compare results and discuss the effects of the various metallic ions, acids, and bases on the intensity of the luminescence.

A table should be prepared showing the compounds present in the different test tubes, whether or not light was emitted, the duration of the light, and its color.

O-54 COLD LIGHT: ITS USES

A commercial product known as Cool Lite is an interesting example of chemiluminescence that you may wish to demonstrate to your students. You can obtain it from a scientific supply house or a retail outlet. The device functions for several hours and has many practical uses, such as enabling a person to read a road map at night when no other light source is available. Your students can no doubt think of other practical uses for the product.

Cold light in the form of fluorescence has a broad range of applications, notably in science-related research (see photographs on student module page 101). Microbiologists use fluorescence as a means of identification of various microorganisms. A certain eye disease in which there is damage to blood vessels may be diagnosed by using a fluorescent dye which is injected into the bloodstream. With the aid of a light source and special filters, a photograph may be taken of the blood vessels in the eye, thus providing a clear record of the condition of the vessels.

Fluorescence has been used in police work to detect and identify drugs such as morphine and LSD. Some forgeries, such as that of counterfeit money, can also be detected with the aid of fluorescent technology. Geologists study minerals, river flow patterns, and trace the paths of underground streams by using fluorescent chemicals.

Chemical and biological research make great use of fluorescent substances in the study of nucleic acids, enzymes, and drugs.

You may wish to have students check on other uses of fluorescent technology. If a UV light is available, you may wish to examine various materials suggested by your students, such as minerals, for their phosphorescent qualities or in the case of postage stamps, to determine the presence of fluorescent inks.

Some of your students may wish to check on other biological organisms that produce light. Several examples are shown in the photographs on page 102 of the student module. Additional questions that might stimulate investigation are: Why do these animals produce light? How do they do this? Why do scientists study the production of light by living organisms? This last question could lead into a discussion of the photograph on page 103 of the student module. How and in what way can these processes discussed in this section in photochemistry be applied to other areas of chemistry and to the study of the functions of the human body?

As an application of the research on cold light, the National Aeronautics and Space Administration sent a probe containing chemicals into outer space. These chemicals, in the presence of ATP, would emit cold light. NASA believed that the presence of ATP denoted higher life-forms. But, as of this time, no detection of ATP has been reported. Some of your more interested students may wish to look into the details of this process. Have them check their library resource center for periodical information or write to NASA for more information.

O-55 CHEMISTRY OF VISION

Light is a form of electromagnetic radiation having a wide range of wavelengths. Humans are capable of detecting with their eyes only a portion of these wavelengths called visible light. The electromagnetic radiation spectrum also includes ultraviolet (above violet) and infrared (below red) light. These wavelengths are not visible to the human eye. You may wish to draw a diagram of the electromagnetic spectrum on the chalkboard or on an overhead transparency to aid in this discussion. (These diagrams may be found in physics, optics, or instrumental chemistry books.)

Point out that the human body functions because of many ongoing, complex chemical reactions. The detection of light (vision) and the transmission of nerve impulses are, in part, the results of chemical reactions. How is the eye able to detect light? Impress upon your students that light is a very active form of energy that is capable of promoting chemical reactions. You may wish to discuss briefly other activities of light, such as causing sunburn, the process of photosynthesis, and the photographic process that occurs on camera film.

You may wish to use a diagram of the human eye in the discussion of the vision process. Point out the retina and, specifically, the rod cells where the compound retinal is located. The rod cells enable humans to see with low amounts of light. To properly function, these cells need vitamin A. A diet deficient in vitamin A causes a decreased amount of retinal in the rod cells resulting in poor night vision. Examine the structural formulas of retinal, vitamin A, and β-carotene, noting the similarity in chemical structures. Discuss the food sources of vitamin A and β-carotene, and relate this to the maintenance of good vision if one eats foods rich in these nutrients.

Reinforce the concepts of *cis* and *trans* isomers that were studied earlier in section *O-49*, pointing out that *cis-trans* represent geometric isomers. Review the examples of structural formulas showing *cis-trans* isomers on page 105 of the student module. The chemistry of vision involves a change in the molecular shape or geometry of the retinal molecule from the *cis*-isomer form to the *trans*-isomer form with light providing the energy to carry out the conversion. Focus attention on the number 11 carbon atom and note that the retinal on page 104 is the *trans*-isomer. Change in the shape of the key molecule retinal begins a series of impulses that are carried to the brain and thus enable one to "see."

In preparation for the experiment *O-56 Photochemical Reaction*, page 106 of the student module discusses the principle of thin-layer chromatography. This technique of separating chemical compounds in a mixture can be used to show the conversion of the *trans*-isomer of azobenzene to the *cis*-isomer by reaction with light. Of great importance to understanding thin-layer chromatography is knowing how the separation works. Focus student attention on the concepts of polarity and nonpolarity of molecules and the interactions of the molecules with the solvent and the gel or adsorbent substance. Discuss the illustrations on page 106 of the student module that show how chromatography separation occurs.

EXPERIMENT
O-56 PHOTOCHEMICAL REACTION

The purpose of this experiment is to demonstrate the light-catalyzed transformation of *trans*-azobenzene to *cis*-azobenzene and the separation of the compounds by thin-layer chromatography.

The reaction which we will study, the transformation of *trans*-azobenzene into *cis*-azobenzene, is called an isomerization. The two materials, *cis*-azobenzene and *trans*-azobenzene, have the same formulas, $C_{12}H_{10}N_2$, but have different structures. It is noteworthy that this type of isomerization of a *cis*- to a *trans*-isomer is the key step in the chemistry of vision. The *only* effect that light has in the total "seeing" process is to cause the isomerization of a molecule called 11-*cis*-retinal to all-*trans*-retinal. Compare the structure and shape of all-*trans*-retinal (student module page 104) to that of 11-*cis*-retinal (student module page 105). All other processes which result in the final registering of a "picture" in the brain are secondary and have nothing to do with light.

Concepts

- Many organic compounds exist as isomers.
- One form of isomerism is *cis-trans*, which involves change in molecular shape or geometry.
- *Cis-trans* transformation may be accomplished by light.
- *Cis-trans* isomers have different physical properties particularly in their degrees of polarity.
- Thin-layer chromatography can be used to separate *cis-trans* isomers because one of the isomers is adsorbed to a surface more strongly than the other.

Objectives

- Explain or diagram the difference between *cis-trans* isomers.
- Relate physical properties to structure.
- Manipulate thin-layer chromatography equipment.
- Determine R_f values for thin-layer chromatography.

Estimated Time Two periods

Student Grouping Pairs

Materials

60 cm^3 toluene
150 cm^3 cyclohexane
0.2 g *trans*-azobenzene
15 capillary tubes
15 wide-mouth round jars and tops
30 TLC strips (Eastman chromagram #6061 Silica gel cut to 2.5 x 10-cm strips)*
UV light source, if available

Advance Preparation Dissolve 0.2 g of *trans*-azobenzene in 10 cm^3 of toluene. Store in a brown bottle. The developing solvent is prepared by adding 50 cm^3 toluene to 150 cm^3 cyclohexane. Prepare both of these just prior to the lab period. Test the experiment beforehand to insure proper chromatographic separation.

Prelab Discussion Discuss the structures of the two isomers shown on page 106 of the student module. Explain to your students that the single pair of dots on the nitrogen is an unshared pair of electrons and the electron pair has a charge. In the *trans*-isomer of azobenzene there is a "balancing" effect of the charge on the molecule, which results in a nonpolar molecule; whereas the concentration of the unshared electron pairs on one side of the *cis*-isomer gives one side of the molecule a negative charge.

You may wish to construct models of the two isomers in order to provide a three-dimensional aid to help the students visualize *cis-trans* isomerization.

Utilize the discussion on page 106 of the student module to explain the principle of thin-layer chromatography which enables this process to separate chemical compounds in a mixture.

Briefly discuss isomer conversion and separation. Demonstrate the techniques of thin-layer chromatography: plate preparation, spotting, and chromatography.

Laboratory Tips Use caps on jars. Carefully spot the material on the TLC plate. Use a pencil (not a pen) to make the mark on the coated side of the plate to indicate where the spot of *trans*-azobenzene is initially placed. Remind students to mark on the end plate where the solvent stopped as soon as they remove the plates from the jar. Caution the students not to touch the gel on the TLC plates but to handle the plates by the edges only. Contamination of the adsorbing surface by residue or moisture can be absorbed into the gel, thus changing the plate's surface characteristics and, possibly, adversely affecting the outcome of the chromatograph. Do not leave the *trans*-isomer solution exposed to light longer than necessary.

TLC plate *B* should be irradiated for 24 hours in sunlight before developing. If a source of ultraviolet light is used, the irradiation time may be reduced to 20 minutes. **Caution:** *If you are using ultraviolet light for the experiment, caution students not to look directly into the light source.* Developing time takes approximately 10 minutes per plate.

Solutions used in this experiment are flammable and, in high concentration, can be toxic. Dispose of organic compounds in waste cans.

Range of Results The calculation of R_f values for *cis-* and *trans*-azobenzene should show: R_f *trans*—0.5 to 0.8; R_f *cis*—0.04 to 0.2.

Postlab Discussion Compare R_f values for the two materials. Relate the movement to isomer form, that is, the polarity of the *cis* form as opposed to the nonpolarity of the *trans* form. The nonpolar form should dissolve in the nonpolar solvent and, hence, be carried farther up the plate. Also, the polar form is attracted to the polar surface of the plate. If plates are not dry, the *cis* form moves farther than expected, but is well behind the *trans* form.

Discuss the significance of a control in the experiment (plate A). What would the results on the irradiated plate mean if there still was one dot and there was no control? If there were two dots after irradiation of plate B,

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*Any commercially available silica gel TLC plates will do. They may be cut to any desired size. The size given in the list is as large as you need. Actually you could get away with plates 1.5 x 5.0-cm if necessary.

You may find commercial TLC plates too expensive. You (and/or your students) can make your own TLC plates in the following manner. Obtain silica gel suitable for thin-layer chromatography (*not* column chromatography) and make a slurry (about 20 g) in a wide-mouth screw cap jar (4 oz) with chloroform (50 cm^3). Place two microscope slides back to back, and, holding the very end of the slides, dip them into the slurry, withdraw them smoothly, carefully separate the two slides, and dry them in an oven (120°C) for ten minutes. Perfect plates will have a thin (but not transparent) layer of silica gel evenly spread over the surface of the plates. Your plates need *not* look perfect in order to work. Make your own before you have your class do the experiment in order to get some idea of what to expect from your homemade TLC plates.

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how might one interpret the results if plate A were not done? Point out how plate A helps to identify these two materials and prevents misinterpretation of the experimental results.

EVALUATION ITEMS

These are suggestions for evaluation items which you may wish to use with your students at various times during the preceding section. The correct answer to each equation is indicated by shading.

1. Chemiluminescence is characterized by the

   A. emission of light.
   B. emission of light and heat.
   C. emission of heat.
   D. none of these

2. In a paper chromatography separation experiment, three amino acids were separated by an acid-alcohol solvent. The following movements were observed:

   Amino acid A moved 30 cm
   Amino acid B moved 20 cm
   Amino acid C moved 1.5 cm
   Solvent front moved 40 cm

   The R_f value for amino acid B is:

   A. 2.00 C. 2.67
   B. 0.50 D. 0.75

3. Describe a demonstration, experiment, or experience that indicates the fact that light is a source of energy.

4. Describe how thin-layer chromatography works. Describe how it might be used in chemical research.

5. Define the term R_f, and describe how it is measured.

6. Describe and define the terms *polar* and *nonpolar*. Relate the terms to the *cis* and *trans* forms of a molecule. Is one form always polar and the other nonpolar?

7. Discuss the chemical interrelationship of β-carotene, vitamin A, and retinal.

8. Explain *cis-trans* isomerization using structural formulas.

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SUGGESTED FILM

Art of Separation. 29 minutes. U.S. Atomic Energy Commission, Division of Public Information, Audiovisual Branch, Washington, DC 20545.

Explains and demonstrates the principles and methods of chromatography.

Drugs: From Aspirin to Hallucinogens

Perhaps one of the more colorful and fascinating applications of the *knowledge* of chemistry is in the field of drugs. Advances in chemistry include the isolation, identification, and highly complex synthesis techniques which have enabled researchers to develop, duplicate, and mass-produce new drugs of all kinds for a wide variety of purposes (illustrated in the photograph on page 108 of the student module).

Because of the wide use of drugs in our society, some students may be interested in expanding their studies to include the medical uses of certain drugs and how these relate to the physiological mechanisms of the human body. Permit your students to form and express their own opinions related to this topic. Bear in mind that the primary objective of this section is to teach the chemistry of drugs, not to become involved in a debate over the social problems of drug use or abuse. Upon learning the chemistry of a number of drug-related compounds, students will begin to recognize that drugs have a great power to heal, to provide relief from suffering, and to do harm.

The Federal government has been active in the development of laws related to the proper and accurate labeling of commerical drugs and to the sale of generic drugs as an aid to the consumer. You may wish to have students obtain additional information from their library resource center, pharmacies, journals, or from subordinate agencies of the Food and Drug Administration, 5600 Fishers Lane, Rockville, MD 20852.

O-57 LET'S START WITH ASPIRIN

The keynote of this opening section is that scientists know little about the actual mechanism of drugs in the human body even though great amounts of time and money are spent on drug research today. A startling example of this, brought out in the student module, is that even some common nonprescription drugs such as aspirin are not clearly understood in terms of how they perform their "miracles" in the human body. You may wish to discuss the premise that one of the difficulties in carrying out comprehensive drug research is due to the limits of our understanding of life functions.

Miniexperiment *What Makes Aspirin Work* Your students have already discussed what aspirin is in terms of a chemical compound. You may wish to ask them to check into what aspirin actually does in providing relief for the human body. Ask them to read the labels of aspirin bottles to determine what each product will do. Then have them check current periodicals to find out what researchers know and do not know about aspirin. What can aspirin do for the body? How does it do this? What are the precautions? Ask students who participated in this project to present this information to the class. Sum up the information, and ask students if this type of knowledge or lack of it might apply to other drugs as well. How does this affect their feelings about these types of drug products? Let your students supply the answers and form their own opinions.

Continue the discussion pointing out briefly some of the history of the modern "wonder" drugs used in today's society. The antibiotic drugs we use today are developed and tested, in part, through microbiological research which studies the effects of various natural and synthetic chemicals against disease-producing organisms. (Refer to the photographs on student module pages 109 and 121.) The observation that certain microorganisms produce their own chemical defenses against other destructive microbes led to the discovery of the first antibiotic drugs.

In your discussion of the action of sulfanilamide on bacteria, you may wish to point out the complex research prerequisites that were required for the development of the sulfa drugs. The study of sulfanilamide's mechanism for destroying bacteria is one example that can be used to provide the students with an appreciation of the arduous tasks of developing and providing safe drugs for human use today.

O-58 ALKALOIDS

Drugs may be most easily classified according to their effects on the human body. As an example, point out that aspirin is a pain killer or analgesic, sulfanilamide is an antibiotic—a class of drugs that kills or halts the growth of living microorganisms. These are classed as alkaloids—chemicals found in plants that contain at least one nitrogen atom. Narcotics and hallucinogens, derivatives of alkaloids, have different physiological effects. Examine and discuss the structural formulas of the alkaloids on pages 110 and 111 along with their uses and effects.

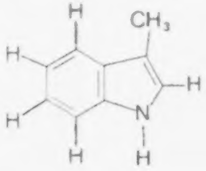
Not all alkaloids are found in plants. Some, as in the venom of the fire ant, are found in animals. Fire ants (see student module page 60) found in South America have become a nuisance to farmers in the southern United States. Their sting, which is much more irritating than that of native American ants, has resulted in isolated cases of deaths among livestock. From a chemical point of view, the most fascinating idea about the venom of the fire ant is that it is the only known nonproteinaceous venom delivered by an animal bite or sting.

As is the case with many drugs, alkaloids can often be beneficial to their host plants or to humans; however, these chemicals can also be deadly toxins. Refer to the structure on student module pages 110 and 111 in discussing nicotine, its uses, and its effects on the human body. Have students check the packages of various insecticides to see if any contain nicotine or nicotine-related compounds. Alkaloids may serve as defense mechanisms for plants since animals often avoid eating plants that contain poisonous alkaloids. It may be that plants which contain alkaloids have a better chance of survival than do those which contain no alkaloids.

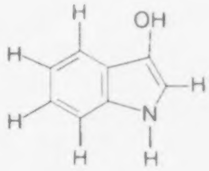
O-59 HALLUCINOGENS: THE "DREAM-MAKERS"

Briefly examine the structural formulas of the hallucinogens found on pages 112 and 113 of the student module to ascertain their relationship to the alkaloid group. The drug lysergic acid diethylamide (LSD) has made headlines in newspapers and magazines, and you may wish to suggest that your students find and bring in articles about this drug. Discuss the historical significance of LSD and its natural source. Then compare the effects that LSD and serotonin have on the brain. Compare these reactions to those of the sulfanilamide and *p*-aminobenzoic acid relationship in section *O-57*.

Discuss the indole ring system (see student module page 113) with your students, and stress its appearance in the molecular structures of hallucinogens. You may wish to discuss with your students other chemical compounds that contain the indole-ring structure. Indole and skatole are degradation products of the amino acid tryptophan and are responsible for the odor of feces. Indoxyl is found in plants of the genus *Indigofera*, and exposure of this chemical to air readily gives indigo, a natural dye.



skatole



indoxyl

Scientists theorize that hallucinogens disrupt the normal chemistry of the brain because these drugs have similar molecular structures to those of chemical compounds necessary for the proper functioning of the brain. Discuss the structural similarity between the molecules of epinephrine and those of mescaline (student module page 114). Some students may wish to check further into the reason for the action of epinephrine on the human body. Your students may wish to research and discuss the known effects of hallucinogenic drugs on living cells in the human body.

O-60 MARIJUANA: PSYCHOACTIVE PLANT

Emphasize that despite much research into the short- and long-term effects of marijuana on the human body and other living organisms, experimental results at this time are still inconclusive. You may wish to have some interested students check on other historical accounts of the use of marijuana in addition to the student module information. The active ingredient, Δ^9-tetrahydrocannabinol, THC, is a nonalkaloid chemical (see pages 115 and 117 of the student module) and is the subject of recent controversy. You may wish to discuss some of the research done pertaining to the harmful effects of THC on the human body. Have students bring in and discuss current information about marijuana as reported in daily newspapers and magazines to supplement this discussion. Other sources of information related to marijuana research may be obtained by writing to the National Institute of Drug Abuse (NIDA), 5600 Fishers Lane, Rockville, MD 20852.

O-61 STIMULANTS

Stimulants represent a broad category of drugs, some of which are commonly found in everyday foods, drinks, and nonprescription medicines. Students may wish to do some research to check on the caffeine levels in samples of soda, coffee, and tea. Point out that caffeine is an alkaloid (see the structural formula on page 117 in the student module). A major point to be stressed is that it appears that these stimulants innervate the body's functions at the beginning of or soon after consumption but later serve to depress these functions. Examine the other alkaloids classified as stimulants (on student module page 118), and compare their structural similarity to that of cocaine. Discuss their uses. Amphetamines have also been classified as stimulants; they have been synthesized and have been shown to produce serious side effects after prolonged or excessive use.

Cocaine, scopolamine, and atropine belong to the tropane class of alkaloids. Structurally, scopolamine is closely related to cocaine, yet, interestingly enough, scopolamine is a common ingredient in nonprescription sleeping tablets while cocaine is considered a dangerous habit-forming drug. You might wish to emphasize that it is virtually impossible to predict whether two drugs having similar structures will have similar effects.

O-62 NARCOTICS: ANALGESIC BUT ADDICTIVE

Although aspirin and morphine are technically analgesics by definition, the latter has a very powerful effect on depressing the functioning of the central nervous system. Discuss the illustrations on page 119 of the student module and the structural formulas of the opiates, noting the slight changes in molecular structure. Discuss the concept of addiction with your students. Students may wish to examine the history of narcotic drugs used for medicinal purposes and research the chemistry of these drugs to explain how they produce their addictive and analgesic effects.

O-63 BARBITURATES: THE SYNTHETICS

Barbiturates are a class of synthetic drugs which act as depressants and have an effect similar to that of narcotics on the central nervous system. The barbiturates prevent the brain from consuming oxygen and storing energy for later use. Discuss the need for extreme caution in the prescription and use of these drugs due to their depressant nature and addictiveness.

Chemically, barbiturates are synthesized via a condensation reaction. Point out that this is the same kind of reaction responsible for the synthesis of nylon and Dacron (see section *O-48*). Two molecules combine with the elimination of water.

A review of the drugs studied in this unit may be initiated by using the *Time Machine* on page 120 of the student module. Highlight the relatively recent discovery of antibiotics. Contrast this information found in the *Time Machine* with the ancient prescription shown at the bottom of page 120. Review with your students that the recorded history of the use of drugs as a way of relieving pain and suffering, regulating various bodily activities, and as part of rituals goes far back in time.

Some students may be interested in researching the natural sources of many drugs used in medicine today such as digitoxin (digoxin) and quinine.

EVALUATION ITEMS

These are suggestions for evaluation items which you may wish to use with your students at various times during the preceding section.

1. Discuss briefly the benefits and the harmful effects of drugs.
2. Drugs introduced into the human body prove to be effective by mimicking the molecular structures of natural body chemicals. Describe how sulfanilamide works as an antibiotic. What compound in the body does this drug mimic?
3. What do all alkaloid drugs have in common?
4. What might you conclude if the molecular structures of two drugs contained the indole-ring system?
5. What are some of the effects of large amounts of THC on the human body as indicated by experimental evidence?
6. What are the physiological effects of barbiturates on the human body which necessitate caution in the prescription and use of these drugs?
7. Discuss the role of the various sciences—chemistry, biology, physics—in the discovery, development, and production of drugs.
8. Considering the many types of drugs and their uses and misuses, provide a *general* definition for the term *drug*.

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Stern, Edward L. *Prescription Drugs and Their Side Effects*. New York: Grosset and Dunlap, 1976.
Information about 150 frequently prescribed drugs, why each drug is prescribed, necessary precautions and side effects, and generic names.

Taking Things Apart and Putting Things Together. American Chemical Society, 1155 16th Street, N.W., Washington, DC 20036. 1976, pp. 14–15, 24–36.
Written for the layperson, there are discussions of antibiotics, vitamins, vaccines, and chemical compounds in the brain.

"Under the Influence of Marijuana." *Science News*, January 29, 1977, p. 73.

SUGGESTED FILMS

Biochemistry and Molecular Structure. Color, 22 minutes. A CHEM Study Film, Modern Learning Aids, Division of Ward's Natural Science Establishment, Rochester, NY 14603.
Sulfanilamide is used as an example of how chemical structure affects biological activity.

Drugs and Medicines—Where They Come From. Color, 10 minutes. Coronet Instructional Films, 65 E. South Water St., Chicago, IL 60601.
Traces the search for drugs from nature to the laboratory.

Drugs and the Nervous System. Color, 16 minutes. Churchill Films, 662 N. Robertson Blvd., Los Angeles, CA 90069.

Drugs for Cancer. Black and white, 29 minutes. University of Southern California, Dept. of Cinema, University Park, Los Angeles, CA 90007.

Dyes—Some Principles of Organic Synthesis. Color, 30 minutes. Encyclopaedia Britannica Educational Corp., 425 N. Michigan Ave., Chicago, IL 60611.
Includes a discussion of sulfanilamide and *p*-amino benzoic acid.

For Tomorrow: Something Better. Color, 25 minutes. Merck, Sharp and Dohme, Film Library, West Point, PA 19486.
Shows the research and development effort in the laboratory to produce pharmaceutical products.

Prescription For Tomorrow. Color, 19½ minutes. A. H. Robins Co., Community Relations Service, 1407 Cummings Dr., Richmond, VA 23220.
Portrayal of the operations of a pharmaceutical manufacturing company.

Summing Up

There are many different ways in which you might conclude this introductory discussion of organic chemistry. Start by asking your students the question posed in the text—why this module has only scratched the surface of this vast subject area. Ask them to list from their previous discussions the various ways that organic chemistry is involved in answering some of the questions and problems posed by our society. As they recall each of the areas in organic chemistry discussed, they should be able to present at least one problem that still needs researching by the organic chemist.

Discuss the lists that your students might have prepared during the opening discussion of the section, *Organic Chemistry*. Now may be a good time for students to review, revise, and update these lists.

Ask students to relate several ways that organic chemistry has affected *their* lives. What new information did they learn to change their attitudes about the way they view their environment? If students collected recent newspaper articles throughout this course, have them review the topics that were discussed.

Allow your students to participate actively in presenting a summing up of their study of organic chemistry. Spend most of the allotted time elicting their opinions and discussing what they learned. Do not spend a great deal of time reviewing structural formulas and concepts. Rather, keep the discussions positive, brief, and without tedious assignments. By focusing on the areas that interested each student, attitudes can be evaluated that might affect the choice and teaching style of the next module.

Some students might be interested in knowing more about the career opportunities available in chemistry. Use this study of organic chemistry as an example and suggest that those interested find out the many areas and opportunities in chemistry available to them. Suggest that they look for information in the career section of their library resource center, write to the American Chemical Society (1155 16th Street, N. W., Washington, DC 20036) and the Association of Manufacturing Chemists (1825 Connecticut Avenue, Washington, DC 20009), and, if possible, talk to those already in the field.

Appendix

Safety

SAFETY IN THE LABORATORY

Proper conduct in a chemistry laboratory is really an extension of safety procedures normally followed each day around your home and in the outside world. Exercising care in a laboratory demands the same caution you apply to driving a car, riding a motorbike or bicycle, or participating in a sport. Athletes consider safety measures a part of playing the game. For example, football players willingly spend a great deal of time putting on equipment such as helmets, hip pads, and shoulder pads to protect themselves from potential injury.

Chemists must also be properly dressed. To protect themselves in the laboratory, they commonly wear a lab apron or a coat and protective glasses. Throughout this course you will use similar items. Hopefully their use will become second nature to you, much as it becomes second nature for a baseball catcher to put on a chest protector and mask before stepping behind home plate.

As you read through a written experimental procedure, you will notice that specific hazards and precautions are called to your attention. Be prepared to discuss these hazards with your teacher and with your fellow students. Always read the entire experimental procedure thoroughly before starting any laboratory work.

A list of general laboratory safety procedures follows. It is not intended that you memorize these safety procedures but rather that you *use* them regularly when performing experiments. You may notice that this list is by no means complete. Your teacher may wish to add safety guidelines that are relevant to your specific classroom situation. It would be impossible to anticipate every hazardous situation that might arise in the chemistry laboratory. However, if you are familiar with these general laboratory safety procedures and if you use common sense, you will be able to handle potentially hazardous situations intelligently and safely. Treat all chemicals with respect, not fear.

GENERAL SAFETY GUIDELINES

1. Work in the laboratory only when the teacher is present or when you have been given permission to do so. In case of accident, notify your teacher immediately.
2. Before starting any laboratory exercise, be sure that the laboratory bench is clean.
3. Put on a laboratory coat or apron and protective glasses or goggles before beginning an experiment.
4. Tie back loose hair to prevent the possibility of its contacting any Bunsen burner flames.
5. Open sandals or bare feet are not permitted in the laboratory. The dangers of broken glass and corrosive liquid spills are always present in a laboratory.
6. Fire is a special hazard in the laboratory because many chemicals are flammable. Learn how to use the fire blanket, fire extinguisher, and shower (if your laboratory has one).
7. For minor skin burns, immediately immerse the burned area in cold water for several minutes. Then consult your teacher for further instructions on possible additional treatment.
8. In case of a chemical splash on your skin, immediately rinse the area with cold water for at least one minute. Consult your teacher for further action.
9. If any liquid material splashes into your eye, wash the eye immediately with water from an eyewash bottle or eyewash fountain.
10. Never look directly down into a test tube—view the contents of the tube from the side. (Why?)
11. Never smell a material by placing your nose directly at the mouth of the tube or flask. Instead, with your hand, "fan" some of the vapor from the container toward your nose. Inhale cautiously.
12. Never taste any material in the laboratory.
13. Never add water to concentrated acid solutions. The heat generated may cause spattering. Instead, as you stir, add the acid slowly to the water or dilute solution.
14. Read the label on a chemical bottle at least *twice* before removing a sample. H_2O_2 is not the same as H_2O.
15. Follow your teacher's instructions or laboratory procedure when disposing of used chemicals.

This symbol represents three of the common hazards in a chemistry laboratory—flame, fumes, and explosion. It will appear with certain experiments in this module to alert you to special precautions in addition to those discussed in this Appendix.

Module Tests

Two module tests follow: one to test knowledge-centered objectives and the other to test skill-centered objectives. If you choose to use either or both of these module tests as they are presented here, duplicate copies for your students. Or, you may wish to select some of the questions from these tests that you feel apply to *your* chemistry course and add additional questions of your own. Either way, make sure that the test you give reflects your emphasis on the chemistry that you and your students experienced in this module.

The skill-centered test will require that you set up several laboratory stations containing materials for your students to examine or work with. You may wish to add additional test items to round out the types of skills you and your students have worked on.

Answers to the test questions in this section are provided. If you wish to use a standard-type answer sheet for this test, one is provided in the appendix of the teacher's guide for *Reactions and Reason*.

ANSWERS FOR KNOWLEDGE-CENTERED MODULE TEST

1. B; **2.** C; **3.** D; **4.** C; **5.** D; **6.** A; **7.** D; **8.** D; **9.** C; **10.** C; **11.** B; **12.** D; **13.** B; **14.** A; **15.** B; **16.** A; **17.** D; **18.** B; **19.** C; **20.** B; **21.** B; **22.** D; **23.** A; **24.** C; **25.** A; **26.** C; **27.** B; **28.** C; **29.** D; **30.** A

Skill-Centered Module Test

Using the skill-centered test items will require certain advance preparations on your part. The numerals in the following list indicate the items for which you will have to prepare special laboratory stations. Be sure to test each of the lab stations before allowing students to determine the answers to the skill-centered items. When students are ready to answer these questions, they should go to the numbered station and follow the directions that are given there and in the printed test item. When they finish with the materials at the station, instruct them to leave the materials in proper order for the next student.

1. Set up a distillation apparatus as shown on page 21 of the student molule.

2. Provide 4 test tubes labeled A, B, C, and D. Mark each tube at the 5-cm_3 and 7-cm_3 levels. Provide a corked flask labeled A containing H_2O; B containing hexane or another aliphatic hydrocarbon; C containing ethanol; and D containing acetone.

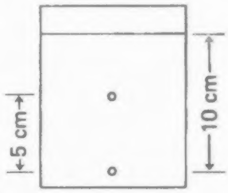
   Liquid X is pentane or another aliphatic hydrocarbon and should be provided in a corked flask. Provide 5 small beakers for pouring, labeled A, B, C, D, and X.

   Provide a waste jar for chemical disposal.

3. Provide a sealable container in which is methyl salicylate. This was made during the synthesis of esters experiment.

4. Provide ball-and-stick models of 1,1-dichloroethylene (A), 1,2-dichloroethane (B), ethylene (C), and 1,2-dichloroethylene (D).

6. Provide a TLC plate with a small spot at the bottom indicating where the sample was applied. Draw a line across the top to indicate where the solvent front stopped. This line should be 10 cm from the bottom spot. Now place a spot on the plate 5 cm from the bottom spot. To make the spots use food coloring or ink.



8. Provide a 25-cm^3 graduated cylinder filled with colored water (use food coloring or ink) to the 13.5-cm^3 level. Place a piece of tape over the top to avoid evaporation.

ANSWERS FOR SKILL-CENTERED MODULE TEST

1. C; **2.** A; **3.** A; **4.** D; **5.** C; **6.** B; **7.** D; **8.** B; **9.** B; **10.** A; **11.** A; **12.** D; **13.** C; **14.** A; **15.** D

FORM AND FUNCTION
Knowledge-Centered Module Test

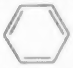
1. Tear gases are examples of lachrymators and they function as

A. nerve gases.
B. alkylating agents.
C. proteins.
D. isomers.

2. A polymer made by a student in the laboratory had the formula $A-(A)_z-A$. If the monomer A has a molecular mass of 130, the molecular mass of the polymer is approximately

A. $130(z-2)$
B. $130(z)$
C. $130(z+2)$
D. $130(3)$

3. The compound which changes the color of a solution of $KMnO_4$ is

A. 

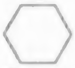
B. CH_3-CH_3

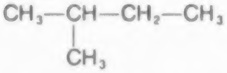
C. CH_4

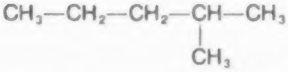
D. $CH_3-CH_2-CH=CH_2$

4. An isomer of $CH_3-CH_2-CH_2-CH_2-CH_3$ is:

A. $CH_3-CH_2-CH_2-CH=CH_2$

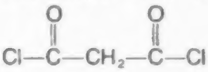
B. 

C. 
$CH_3-\underset{\displaystyle CH_3}{\underset{|}{CH}}-CH_2-CH_3$

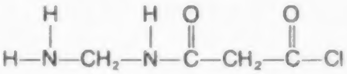
D. 
$CH_3-CH_2-CH_2-\underset{\displaystyle CH_3}{\underset{|}{CH}}-CH_3$

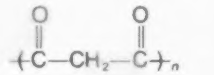
5. A certain copolymer forms by eliminating HCl and has the structure $\leftarrow\!\!\!\!\!\!\;(A-B)\!\!\rightarrow_n$.

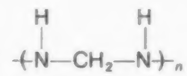
If A is $H_2N-CH_2-NH_2$ and B is

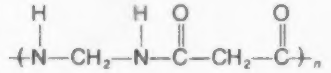

$Cl-\overset{\displaystyle O}{\overset{\|}{C}}-CH_2-\overset{\displaystyle O}{\overset{\|}{C}}-Cl$

the repeating unit for the copolymer is:

A. 
$H-\overset{\displaystyle H}{\overset{|}{N}}-CH_2-\overset{\displaystyle H}{\overset{|}{N}}-\overset{\displaystyle O}{\overset{\|}{C}}-CH_2-\overset{\displaystyle O}{\overset{\|}{C}}-Cl$

B. 
$+\!\!\left(\overset{\displaystyle O}{\overset{\|}{C}}-CH_2-\overset{\displaystyle O}{\overset{\|}{C}}\right)\!\!+_n$

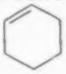
C. 
$+\!\!\left(\overset{\displaystyle H}{\overset{|}{N}}-CH_2-\overset{\displaystyle H}{\overset{|}{N}}\right)\!\!+_n$

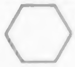
D. 
$+\!\!\left(\overset{\displaystyle H}{\overset{|}{N}}-CH_2-\overset{\displaystyle H}{\overset{|}{N}}-\overset{\displaystyle O}{\overset{\|}{C}}-CH_2-\overset{\displaystyle O}{\overset{\|}{C}}\right)\!\!+_n$

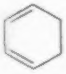
6. Many organic insecticides are

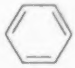
A. chlorinated hydrocarbons.
B. fatty acids.
C. polyalcohols.
D. amines.

7. The correct structure for benzene is:

A. 

C. 

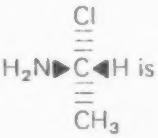
B. 

D. 

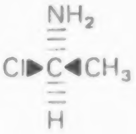
8. The major use of insect sex attractants is to

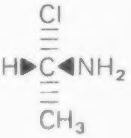
A. protect insects from prey.
B. increase the insect population.
C. create new strains of insects.
D. offer an alternative to the widespread use of insecticides.

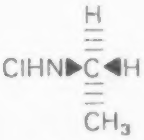
9. Choose the optical isomer of

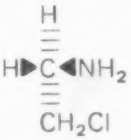

$\begin{array}{c} Cl \\ \vdots \\ H_2N\blacktriangleright C\blacktriangleleft H \\ \vdots \\ CH_3 \end{array}$ is

from the structures below.

A. 
$\begin{array}{c} NH_2 \\ \vdots \\ Cl\blacktriangleright C\blacktriangleleft CH_3 \\ \vdots \\ H \end{array}$

C. 
$\begin{array}{c} Cl \\ \vdots \\ H\blacktriangleright C\blacktriangleleft NH_2 \\ \vdots \\ CH_3 \end{array}$

B. 
$\begin{array}{c} H \\ \vdots \\ ClHN\blacktriangleright C\blacktriangleleft H \\ \vdots \\ CH_3 \end{array}$

D. 
$\begin{array}{c} H \\ \vdots \\ H\blacktriangleright C\blacktriangleleft NH_2 \\ \vdots \\ CH_2Cl \end{array}$

10. The products of the complete combustion of nonane (C_9H_{20}) are:

A. H_2, CO_2, and O_2
B. H_2O and CO
C. H_2O and CO_2
D. H_2O and C

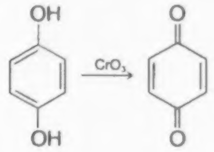
11. An element usually found in explosives is

A. chlorine.
B. nitrogen.
C. aluminum.
D. sulfur.

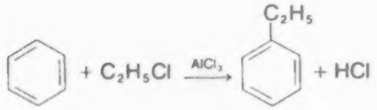
12. An addition reaction is represented by:

A. $C_2H_6 + Cl_2 \longrightarrow C_2H_5Cl + HCl$

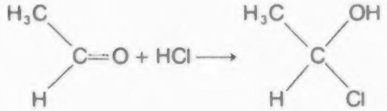
B.



C.

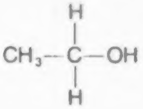


D.



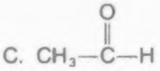
13. The compound which contains carbon in the highest oxidation state is:

A.



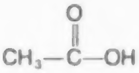
$CH_3-\underset{H}{\overset{H}{C}}-OH$

C.



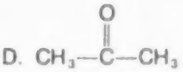
$CH_3-\overset{\overset{O}{\|}}{C}-H$

B.



$CH_3-\overset{\overset{O}{\|}}{C}-OH$

D.



$CH_3-\overset{\overset{O}{\|}}{C}-CH_3$

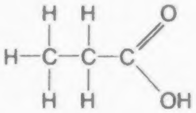
14. A method suitable for increasing the alcoholic content of a ferment is

A. distillation.
B. filtration.
C. isomerization.
D. neutralization.

15. Chemiluminescence is

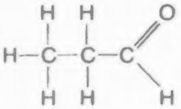
A. the emission of "warm" light.
B. the emission of "cold" light.
C. converting a *trans* isomer to its *cis* form.
D. converting a *cis* isomer to its *trans* form.

16. The molecule represented by the following organic structure is a(n)



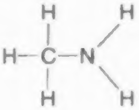
A. carboxylic acid.
B. aldehyde.
C. alcohol.
D. amine.

17. The molecule represented by the following organic structure is a(n)



A. amine.
B. ketone.
C. carboxylic acid.
D. aldehyde.

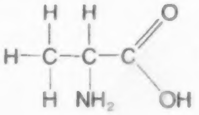
18. The molecule represented by the following organic structure is a(n)



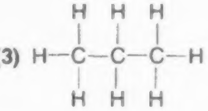
A. acid.
B. amine.
C. ether.
D. ester.

19. Which of the following organic structures is an alkane?

(1)

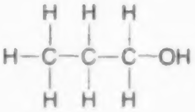


(3)



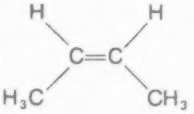
$H-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-H$

(2)



$H-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-OH$

(4)



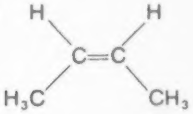
A. (1)
B. (2)
C. (3)
D. (4)

20. Soaps and detergents are useful as cleaning agents because they act as wetting agents to 'dissolve' materials which are water insoluble. Such material might be

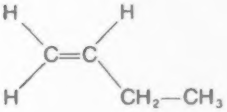
A. salt. B. oil. C. alcohol. D. vinegar.

21. Consider the four possible structures below with the formula C_4H_8.

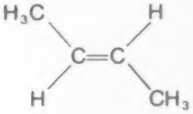
(1)



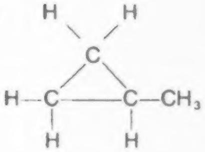
(2)



(3)



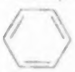
(4)



Cis-trans isomerism is illustrated by:

A. 1 and 2 B. 1 and 3 C. 2 and 3 D. 2 and 4

22. The compound most likely to dissolve in water is:

A.  C. $CH_3—O—CH_3$

B. $CH_3—CH_3$ D. $CH_3—CH_2—CH_2OH$

23. In an experiment a student separated a *cis* isomer from its *trans* isomer. It was found that the *cis* isomer moved up the chromatography plate a distance of 2.0 cm while the *trans* isomer moved up the same plate 3.0 cm. If the solvent traveled a distance of 6.0 cm, the R_f value for the *cis* isomer is:

A. 0.33 B. 0.50 C. 2.0 D. 3.0

24. The compound most likely to burn is:

A. NaCl B. CO_2 C. $C_{10}H_{22}$ D. $CaSO_4$

25. An octane rating of 92 is equal to a mixture of

A. 92% isooctane and 8% *n*-heptane.
B. 92% isooctane and 8% hexane.
C. 92% octane and 8% *n*-heptane.
D. 92% octane and 8% hexane.

26. Analysis of a compound made by a student in the laboratory showed that it contained only C and H. What prediction can be made concerning its solubility?

A. The compound is soluble in neither water nor benzene.
B. The compound is soluble in both water and benzene.
C. The compound is soluble in benzene but not in water.
D. The compound is soluble in water but not in benzene.

27. The series of chemical reactions that convert N_2 to NO_3^- and then to N_2 illustrates

A. isomerization. C. combustion.
B. recycling. D. photosynthesis.

28. The ability of drugs to enter the metabolic cycle is based on their ability to

A. be oxidized. C. mimic body chemicals.
B. be reduced. D. dissolve in fatty tissue.

29. The high boiling point of H_2O and low molecular-weight alcohols is due to

A. ionic bonding. C. van der Waals forces.
B. covalent bonding. D. hydrogen bonding.

30. In determining the expected reactivity of an organic compound, one should begin by examining its

A. functional group(s).
B. approximate molecular weight.
C. solubility in water and other solvents.
D. boiling point and its melting point.

FORM AND FUNCTION

Skill-Centered Module Test

1. The apparatus displayed at this station would be used in a(n)

A. ester synthesis.
B. solubility.
C. fractional distillation.
D. ammonia synthesis.

2. Go to station #2 where you will find four test tubes labeled A, B, C, and D in the test tube rack. The 5-cm^3 level is indicated on each by a ring. Fill tube A with liquid A to the mark. Repeat this procedure using the other three test tubes and liquids. Now add liquid X to each of the tubes to the second ring or mark. Liquid X is *not* soluble in liquid:

A. A B. B C. C D. D

WHEN FINISHED EMPTY ALL TUBES INTO THE WASTE DISPOSAL CONTAINER PROVIDED.

3. Go to station #3. The odor of the chemical in the container most closely resembles that of a(n)

A. peppermint.
B. banana.
C. orange.
D. pineapple.

BEFORE LEAVING BE SURE TO RECAP THE CONTAINER.

4. Go to station #4. Examine the models provided and determine which of the models represents the molecule 1, 2-dichloroethylene. The correct model is:

A. A B. B C. C D. D

5. Which of the following pairs of compounds below would you combine to synthesize propyl butyrate?

A. butyl alcohol and propyl alcohol
B. butyl alcohol and propionic acid
C. propyl alcohol and butyric acid
D. butyric acid and propionic acid

6. Go to station #6 and, using the TLC plate provided, calculate the R_f value for the chromatographed material. The R_f value for the material is:

A. 2.0 B. 0.5 C. 2.0 cm D. 0.5 cm

7. Which of the following would not normally be used in the synthesis of a soap?

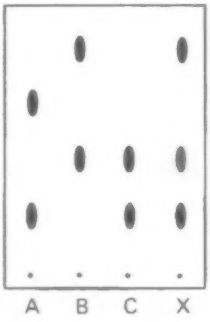
A. animal fat
B. NaOH
C. vegetable oil
D. HCl

8. Go to station #8 and examine the partially filled graduated cylinder, and determine the volume of liquid it contains. The volume of liquid contained in the graduated cylinder is:

A. 11.5 cm^3
B. 13.5 cm^3
C. 12.0 cm^3
D. 13.0 cm^3

9. Examine the thin layer chromatographic plate pictured below. The unknown (X) most probably is:

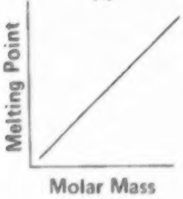
A. a mixture of A and B.
B. a mixture of B and C.
C. a mixture of A and C.
D. none of these



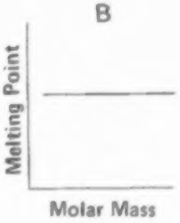
10. Examine the data below. Which graph best represents the relationship between molar mass and melting point?

Substance	*Molar mass*	*Melting point (°C)*
A	32	−97.8
B	46	−117.8
C	60	−127.0
D	74	−136.8

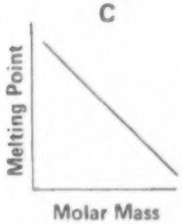
A



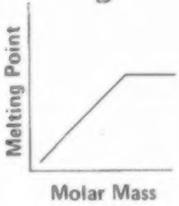
B



C



D



11. Based on the data below, which substance is most likely to be an organic compound?

A. A B. B C. C D. D

Substance	*Solubility in*		*Combustible*	*Melting Point*
	Water	*Ethanol*		
A	I	S	Yes	10°C
B	S	I	No	300°C
C	I	S	No	50°C
D	I	I	Yes	300°C

I = insoluble
S = soluble

12. Yield, the amount of product formed in a chemical reaction from a given amount of reactant, is a concept associated with chemical synthesis. 4.6 g of ethyl alcohol (C_2H_5OH) are added to sufficient benzoic acid in an esterification synthesis. After the reaction, 12.0 g of ethyl benzoate are produced. The percent yield for the reaction is:

A. 60 percent
B. 75 percent
C. 50 percent
D. 80 percent

13. A student has an unknown compound that he or she suspects might be an organic acid of low molecular weight. To begin an identification of the unknown and to test this theory, the student should first determine

A. the boiling point.
B. solubility in water.
C. the pH of an aqueous solution of the compound.
D. if it will decolorize a solution of $KMnO_4$.

14. If you were to build a model of isopropyl alcohol (2-propanol) you would connect the number 2 carbon atom to

A. 2 carbon atoms, 1 hydrogen atom, and 1 oxygen atom.
B. 2 carbon atoms and 2 hydrogen atoms.
C. 1 carbon atom, 2 hydrogen atoms, and 1 oxygen atom.
D. 1 carbon atom, 1 hydrogen atom, and 2 oxygen atoms.

15. When conducting organic chemistry experiments one should always

A. dispose of chemicals in proper disposal area or container.
B. be careful to check for flammable materials at other lab stations before using a flame.
C. avoid prolonged periods of contact with or inhalation of organic chemicals and their vapors.
D. all of the above

Materials List

Quantities are for a class of 30 students working in pairs.

*Optional Items. These items depend on teacher choice. We have listed substitutions in the experiment discussion. Consult the specific experiment in the teacher's guide to determine use and quantities.

NONEXPENDABLE MATERIALS

Item	*Experiment*	*Amount*
Balls, Styrofoam, 20-mm diameter (*or* model kits)	8, 9, 51	300
Balls, Styrofoam, 25-mm diameter (*or* model kits)	8, 9, 51	120
Ball-peen hammer	10	1
Beakers, 50-cm^3	48	15
Beakers, 250-cm^3	13, 40, 42	30
Beakers, 400-cm^3	13, 38, 40, 42	15
Bunsen burners	10, 38, 40, 42	15
Burets and clamps, 50-cm^3	40, 48	5–10
Clamps, universal	13, 38	15
Clock, for timing	13	1
Corks, for test tubes	17, 53	75
Dropping bottles, 50-cm^3	40, 53	5
Erlenmeyer flasks, 125-cm^3	13	15
Erlenmeyer flasks, 250-cm^3	53	15
Erlenmeyer flasks, 500-cm^3	53	15
Funnels and supports	40	15
Graduated cylinders, 10-cm^3	25, 38, 40, 42, 48, 53	15
Graduated cylinders, 50-cm^3	13	15
Jars, wide-mouth with lids	56	15
Medicine droppers	42	15
Mirrors(s)	51	1–5
Model kits, molecular (ball-and-stick) (*or* Styrofoam balls)	8*, 9*, 51*	15*
Ring stands and rings	10, 13, 38, 40, 42	17
Rubber stoppers, assortment	—	—
Rubber stoppers, #5, two-hole for 125-cm^3 Erlenmeyer flasks	13	15
Rubber tubing	40	1 m
Spatulas	25, 38, 53	15
Stirring rods	40, 42	15
Test tubes, 13 x 100-mm	17, 25, 40, 53	75
Test tubes, 18 x 150-mm	13, 38, 42	45
Test-tube clamps	—	15
Test-tube racks	17, 25, 53	15
Thermometers, −10°C to 110°C	13, 38	15
Thermometers, −10°C to 260°C	40	15
Toothpicks	8*, 9*, 51*	5 boxes*
Triangles, clay	40	15
UV light source	56*	1*
Wash bottles	40	15
Wire gauze, asbestos centers	13, 38, 40, 42	15
Wire gauze, plain	10, 40	15

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EXPENDABLE MATERIALS

Item	*Experiment*	*Amount*
Acetic acid, glacial	38, 40	275 cm^3
Acetic anhydride	40	175 cm^3
Acetone	48*	80 cm^3*
Adipyl chloride	48	15 g
Amyl alcohol (*n*-pentyl alcohol *or* 1-pentanol)	38	50 cm^3
Aspirin, commercial	40	15 tablets
trans-Azobenzene	56	0.2 g
Boiling chips	13, 38	5 g
Calcium carbonate	10, 25	25 g
Can lids, 10-cm diameter	10, 40	45
Chromatography sheets, thin layer, 2.5 x 10-cm (Eastman Chromatogram #6061, silica gel)	56	30 sheets*
Chromium(III) chloride	53	10 g
Copper(II) sulfate, pentahydrate	53	10 g
Cyclohexane	17, 56	200 cm^3
Cyclohexene	17	50 cm^3
para-Dichlorobenzene	10, 25	25 g
Ethyl alcohol (ethanol), denatured	25, 42, 48*	1 liter
Filter paper, 12.5-cm diameter	40	15 sheets
Glass tubing, 6-mm diameter	13	15 lengths
Hexamethylene diamine	48	15 g
n-Hexane (see Petroleum ether)		
Hydrochloric acid, conc.	17, 40, 53	150 cm^3
Hydrogen peroxide, 3 percent	53	200 cm^3
Ice	13, 40	—
Iron(III) chloride	40	2 g
Litmus paper, red and blue	40	1 vial each
Luminol	53	3 g
Magnesium sulfate	53	10 g
Melting-point tubes (capillary)	40, 56	45
Methyl alcohol (methanol)	38, 40	400 cm^3
Mineral oil	10, 40, 42	2100 cm^3
Naphthalene	10	5 g
Octyl alcohol (1-octanol)	38	50 cm^3
Paper clips (or 150-cm length copper wire)	48	15
Paraffin	10	5 g
n-Pentyl alcohol (see Amyl alcohol)		
Petroleum ether *or* *n*-hexane (Skelly B, b.p. 60–80°C)	25, 48	400 cm^3
Potassium chloride	53	10 g
Potassium iron(III) cyanide	53	10 g
Potassium permanganate	17	2 g
2-Propanol (2-propyl alcohol)	13	300 cm^3
Salicylic acid	38, 40	150 g
Sodium bicarbonate, $NaHCO_3$	40	10 g
Sodium chloride	10, 25, 42	850 g
Sodium hydroxide	42, 48, 53	200 g
Sucrose (sugar)	10, 25	25 g
Sulfuric acid, conc.	38, 40	100 cm^3
Toluene	17, 25, 40, 56	325 cm^3
Vegetable oil *or* animal fat	42	150 cm^3

Index

Acid(s)
  carboxylic, 53–54
  organic, 53
Alcohol(s), 33–37
  classification of, 35
  defined, 33–34
  diethyl ether, 34
  distilled, 36
  ethyl, 34, 36
  fermented, 36
  methyl, 34, 36
  poly-, 37
  primary, 35, 41
  secondary, 35, 41
  tertiary, 35, 42
Aldehydes, 41–43
Alkaloids, 75
Alkanes, 18–19
  cyclo, 29
Alkenes, 19
Alkylating agents, 39
Alkynes, 19
Amines, 59–61
Anesthetics, 29–30
Aromatic compounds, 30–32
Aspirin
  mechanism of, 75
  synthesis of, 54–55

Barbiturates, 77
Base(s), 59–62
  amine functional group, 59–61
  solubility, 59
Benzene ring, 30–31
Benzopyrene, 31–32
Berthelot, Marcellin, 14
Bioluminescence, 70–71
Bombardier bettle, 43
Bond(s), 28–32
  covalent, 15
  double, 15, 19, 28
  reactivities of, 28–29
  single, 18
  triple, 15, 19, 28

Carbamates, 48
Carbon, 14–15
Carbon cycle, 62
Carbonyl group, 41
Carcinogen, 32, 39
Catalytic converters, 23
Chemical warfare, 38, 40, 43
Chemiluminescence, 70–71
Chemistry, organic, 14
Chromatography, thin-layer, 72
Cold light, 70–71
Combustibility, of compounds, 21–22
Cycloalkanes. *See* Alkanes, cyclo

DDT, 45–46
Detergents, 56, 58
Distillation
  destructive, 36
  fractional, 23–24, 26
Drugs, 74–77
Dynamite. *See* Explosives

Engine, internal combustion, 22
Esters, 51
  preparation of, 51–53
Explosives, 28–29, 32

Fats, 56–57
Fluorescence, 71
Fractional distillation. *See* Distillation
Functional groups, 33–35
Fuels
  fossil, 18
  energy, 17–18

Gas(es)
  mustard, 39
  nerve, 39
Gasoline, additives, 22–23
Geminol diols, 37
Glycerin. *See* Glycerol
Glycerol, 36
Glucose, 17

Haber process, 61
Hallucinogens, 76
Hydrocarbons, 16–24
  chlorinated, 45–46
  oxidized, 33–34
  reactions of, 28–29, 31–32
  saturated, 18
  separation of, 23
Hydroxyl group, 35

Indole ring system, 76
Insecticides, 45, 47
Irritants, 38–39
Isomerism, 20
  mirror image, 67–68
Isomers, 20
  cis, 29, 72–74
  trans, 29, 72–74

Ketones, 41–43

Light, 70–72
LSD, 76
Luminol, 70
Lysergic acid diethylamide. *See* LSD

Macromolecules, 63
Marijuana, 76
Methane, as energy source, 17–18
Models
  ball-and-stick, 20
  branched-chain, 21
  mirror-image molecular, 67–68
  straight-chain molecular, 19–20
Mothballs, 31–32
Mustard gases, 39

Naphtha, 31–32
Narcotics, 77
Nerve gases, 39
Nicotine, 32, 60
Nitrogen, 59–61
  cycle, 61–62
  molecular, 61–62
Nitroglycerin. *See* Explosives
Nobel, Alfred, 32
Nylon 66, synthesis of, 64–65

Oil(s), 56
  uses of, 25
Organic compounds, nomenclature, 41–42
Organophosphates, 47–48
Oxidation, 33–34

PAN, 38–39
PCB, 46–47
Peracyl nitrate. *See* PAN
Pesticides, 44–49
Petroleum, 23
Phosphates, 58
Photochemistry, 70–71
Photosynthesis, 17
Poisons, 38–40
Pollution, 18, 58
Polyalcohols, 37
Polychlorinated biphenyl. *See* PCB
Polychlorinated hydrocarbons. *See* PCB and PVC
Polychlorinated vinyl chloride. *See* PVC
Polymerization reactions
  addition, 67
  condensation, 67
Polymers, 63–67
  defined, 63–64
  natural, 67
  properties, 65–67
  synthetic, 67
PVC, 46–47

Reactions, addition, 28, 42
Reduction, 33–34
Ring(s), fused, 31–32
Rubber, 66–67

Sex attractants, 48–49
Soap(s), 56–58
  preparation of, 57–58
  solubility, of compounds, 36–37
Stimulants, 76–77

TEL, 23
Tetraethyl lead. *See* TEL
TNT. *See* Explosives
Triglycerides, 56-57
Trinitrotoluene. *See* Explosives

Urea, 14–15, 62

Vision, chemistry of, 71–72
Vital force theory, 14

Water, 33–35, 56
Wax(es), 57
Wöhler, Friedrich, 14

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Table of International Relative Atomic Masses*

Element	Symbol	Atomic Number	Atomic Mass
Actinium	Ac	89	227.0
Aluminum	Al	13	27.0
Americium	Am	95	(243)**
Antimony	Sb	51	121.8
Argon	Ar	18	39.9
Arsenic	As	33	74.9
Astatine	At	85	(210)
Barium	Ba	56	137.3
Berkelium	Bk	97	(247)
Beryllium	Be	4	9.01
Bismuth	Bi	83	209.0
Boron	B	5	10.8
Bromine	Br	35	79.9
Cadmium	Cd	48	112.4
Calcium	Ca	20	40.1
Californium	Cf	98	(251)
Carbon	C	6	12.0
Cerium	Ce	58	140.1
Cesium	Cs	55	132.9
Chlorine	Cl	17	35.5
Chromium	Cr	24	52.0
Cobalt	Co	27	58.9
Copper	Cu	29	63.5
Curium	Cm	96	(247)
Dysprosium	Dy	66	162.5
Einsteinium	Es	99	(254)
Erbium	Er	68	167.3
Europium	Eu	63	152.0
Fermium	Fm	100	(257)
Fluorine	F	9	19.0
Francium	Fr	87	(223)
Gadolinium	Gd	64	157.3
Gallium	Ga	31	69.7
Germanium	Ge	32	72.6
Gold	Au	79	197.0
Hafnium	Hf	72	178.5
Helium	He	2	4.00
Holmium	Ho	67	164.9
Hydrogen	H	1	1.008
Indium	In	49	114.8
Iodine	I	53	126.9
Iridium	Ir	77	192.2
Iron	Fe	26	55.8
Krypton	Kr	36	83.8
Lanthanum	La	57	138.9
Lawrencium	Lr	103	(260)
Lead	Pb	82	207.2
Lithium	Li	3	6.94
Lutetium	Lu	71	175.0
Magnesium	Mg	12	24.3
Manganese	Mn	25	54.9
Mendelevium	Md	101	(258)
Mercury	Hg	80	200.6
Molybdenum	Mo	42	95.9
Neodymium	Nd	60	144.2
Neon	Ne	10	20.2
Neptunium	Np	93	237.0
Nickel	Ni	28	58.7
Niobium	Nb	41	92.9
Nitrogen	N	7	14.0
Nobelium	No	102	(259)
Osmium	Os	76	190.2
Oxygen	O	8	16.0
Palladium	Pd	46	106.4
Phosphorus	P	15	31.0
Platinum	Pt	78	195.1
Plutonium	Pu	94	(244)
Polonium	Po	84	(209)
Potassium	K	19	39.1
Praseodymium	Pr	59	140.9
Promethium	Pm	61	(145)
Protactinium	Pa	91	231.0
Radium	Ra	88	226.0
Radon	Rn	86	(222)
Rhenium	Re	75	186.2
Rhodium	Rh	45	102.9
Rubidium	Rb	37	85.5
Ruthenium	Ru	44	101.1
Samarium	Sm	62	150.4
Scandium	Sc	21	45.0
Selenium	Se	34	79.0
Silicon	Si	14	28.1
Silver	Ag	47	107.9
Sodium	Na	11	23.0
Strontium	Sr	38	87.6
Sulfur	S	16	32.1
Tantalum	Ta	73	180.9
Technetium	Tc	43	(97)
Tellurium	Te	52	127.6
Terbium	Tb	65	158.9
Thallium	Tl	81	204.4
Thorium	Th	90	232.0
Thulium	Tm	69	168.9
Tin	Sn	50	118.7
Titanium	Ti	22	47.9
Tungsten	W	74	183.8
Uranium	U	92	238.0
Vanadium	V	23	50.9
Xenon	Xe	54	131.3
Ytterbium	Yb	70	173.0
Yttrium	Y	39	88.9
Zinc	Zn	30	65.4
Zirconium	Zr	40	91.2

*Based on International Union of Pure and Applied Chemistry (IUPAC) values (1975).

**Numbers in parentheses give the mass numbers of the most stable isotopes.

PERIODIC TABLE OF THE ELEMENTS

200.6 — atomic mass
Hg — symbol
Mercury — name
80 — atomic number

IA	IIA	IIIB	IVB	VB	VIB	VIIB	← VIIIB	VIIIB	VIIIB →	IB	IIB	IIIA	IVA	VA	VIA	VIIA	VIIIA
1.008 **H** Hydrogen 1																	4.00 **He** Helium 2
6.94 **Li** Lithium 3	9.01 **Be** Beryllium 4											10.8 **B** Boron 5	12.0 **C** Carbon 6	14.0 **N** Nitrogen 7	16.0 **O** Oxygen 8	19.0 **F** Fluorine 9	20.2 **Ne** Neon 10
23.0 **Na** Sodium 11	24.3 **Mg** Magnesium 12											27.0 **Al** Aluminum 13	28.1 **Si** Silicon 14	31.0 **P** Phosphorus 15	32.1 **S** Sulfur 16	35.5 **Cl** Chlorine 17	39.9 **Ar** Argon 18
39.1 **K** Potassium 19	40.1 **Ca** Calcium 20	45.0 **Sc** Scandium 21	47.9 **Ti** Titanium 22	50.9 **V** Vanadium 23	52.0 **Cr** Chromium 24	54.9 **Mn** Manganese 25	55.8 **Fe** Iron 26	58.9 **Co** Cobalt 27	58.7 **Ni** Nickel 28	63.5 **Cu** Copper 29	65.4 **Zn** Zinc 30	69.7 **Ga** Gallium 31	72.6 **Ge** Germanium 32	74.9 **As** Arsenic 33	79.0 **Se** Selenium 34	79.9 **Br** Bromine 35	83.8 **Kr** Krypton 36
85.5 **Rb** Rubidium 37	87.6 **Sr** Strontium 38	88.9 **Y** Yttrium 39	91.2 **Zr** Zirconium 40	92.9 **Nb** Niobium 41	95.9 **Mo** Molybd'm 42	(97) **Tc** Technetium 43	101.1 **Ru** Ruthenium 44	102.9 **Rh** Rhodium 45	106.4 **Pd** Palladium 46	107.9 **Ag** Silver 47	112.4 **Cd** Cadmium 48	114.8 **In** Indium 49	118.7 **Sn** Tin 50	121.8 **Sb** Antimony 51	127.6 **Te** Tellurium 52	126.9 **I** Iodine 53	131.3 **Xe** Xenon 54
132.9 **Cs** Cesium 55	137.3 **Ba** Barium 56	138.9 **La*** Lanthanum 57	178.5 **Hf** Hafnium 72	180.9 **Ta** Tantalum 73	183.8 **W** Tungsten 74	186.2 **Re** Rhenium 75	190.2 **Os** Osmium 76	192.2 **Ir** Iridium 77	195.1 **Pt** Platinum 78	197.0 **Au** Gold 79	200.6 **Hg** Mercury 80	204.4 **Tl** Thallium 81	207.2 **Pb** Lead 82	209.0 **Bi** Bismuth 83	(209) **Po** Polonium 84	(210) **At** Astatine 85	(222) **Rn** Radon 86
(223) **Fr**† Francium 87	226.0 **Ra** Radium 88	(227) **Ac**** Actinium 89	‡ 104	‡ 105	‡ 106												

*	140.1 **Ce** Cerium 58	140.9 **Pr** Praseody'm 59	144.2 **Nd** Neodymium 60	(145) **Pm** Promethium 61	150.4 **Sm** Samarium 62	152.0 **Eu** Europium 63	157.3 **Gd** Gadolinium 64	158.9 **Tb** Terbium 65	162.5 **Dy** Dysprosium 66	164.9 **Ho** Holmium 67	167.3 **Er** Erbium 68	168.9 **Tm** Thulium 69	173.0 **Yb** Ytterbium 70	175.0 **Lu** Lutetium 71
**	232.0 **Th** Thorium 90	231.0 **Pa** Protactinium 91	238.0 **U** Uranium 92	237.0 **Np** Neptunium 93	(242) **Pu** Plutonium 94	(243) **Am** Americium 95	(245) **Cm** Curium 96	(245) **Bk** Berkelium 97	(251) **Cf** Californium 98	(254) **Es** Einsteinium 99	(254) **Fm** Fermium 100	(256) **Md** Mendel'm 101	(254) **No** Nobelium 102	(257) **Lr** Lawrencium 103

†The most stable known isotopes are shown in parentheses.

‡The discovery of elements 104, 105, and 106 has been claimed by both American and Soviet scientists. The Americans have suggested the name *rutherfordium* and *hahnium* for 104 and 105; the Soviets have suggested the names *kurchatovium* and *nielsbohrium* for these same elements. No name has yet been proposed for element 106.

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